Bridge River Water Use Plan

BRGMON-2 Carpenter Reservoir Riparian Vegetation Monitoring

Implementation Year 4

Reference: BRGMON-2

Period: 2016

Splitrock Environmental Sekw'el'was
PO BOX 798
Lillooet BC
V0K 1V0

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Splitrock Environmental
Odin Scholz B.Sc.
Pascale Gibeau R.P.Bio.

March 20, 2018

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Executive Summary

This report represents the second year of monitoring of Component 2 for the BRGMON-2 Carpenter Reservoir Riparian Vegetation Monitoring project in 2016. The management question for Component 2 asks whether the implementation of a short term (5yr) intensive reservoir re-vegetation program results in benefits that were equal to or greater than that which were expected from implementation of the O3-2i operating alternative. The re-vegetation program is being carried out under the BRGWORKS-1 program implemented in 2014. This report presents the results of 2016 monitoring of both the 2014 and 2015 re-vegetation trials as well as some of the early results of the 2016 re-vegetation efforts. BRGMON-2 monitoring assessed success of trials in terms of survival, per cent cover and vigor. BRGWORKS-1 seeding, planting and live-stake cuttings trials were all evaluated.

The targeted re-vegetation trials have been carried out across 5 terrain types at the west end of Carpenter Reservoir. Terrain types are Steep Beach, Shallow Beach the Gun Creek Fan West and Gun Creek Fan East, the Low Mud Flat and the Steep Alluvial Fan. Trials initiated in 2014 at each of four terrain classes showed in general, a marked decline in survival between 2015 and 2016. Carpenter Reservoir water levels rose early in 2015, causing a short establishment and growing season for some elevations.

At the Steep Beach planting trials with herbaceous species have had very low survival from 2015 trials and some persistence of 2014 lakeshore sedge trials. 2014 and 2015 Live stake cuttings trials at the Steep Beach have met with mixed success with 4 of 5 planted polygons having moderate survival success and one 2015 polygon proving a near complete failure.

At the Shallow Beach terrain 2015 planted polygons also met with very low survival. Nominal successes were observed in 2014 *C. lenticularis* planting strips and plots at low elevation on the Shallow beach. Live stake cuttings patch planted in 2014 continued with very low success while the 2015 polygon had almost 25% survival.

The 2015 planting treatments at the Low Mud Flat appear to be surviving well in lieu of relatively short establishment period prior to inundation. The biggest disturbance on the Low Mud Flat *C. lenticularis* plantings from 2015 appears to be planted plugs being extruded from the ground via floatation while inundated. When comparing 2015 planting and control sites on the Low Mud Flat, there was no apparent difference in natural recruitment. On the Low Mud Flat as well as on the Gun Creek Fan East side seeding trials conducted in 2015 resulted in no additional recruitment of C. lenticularis. On the Low Mud Flat the seeding trial polygon located at the lowest elevation was observed with naturally recruiting sedge seedlings however, no plants over one season old were observed. Trials with fall rye (S*ecale cereale*) seeding in 2015 were intended to provide temporary wildlife habitat value, biomass, and microsite modification, as well as potentially recruit naturally colonizing seed. However, with early inundation, young

plants only grew to about 20cm tall before they were flooded, little residual biomass remained by 2016 and there was not evidence of seedling recruitment.

On the Gun Creek Fan 2015 plantings of bluejoint reedgrass are having some initial establishment success in the upper drawdown and on the left bank of Gun Creek.

Generalized Linear Mixed Models suggest that, all else being constant, year had a large significant negative effect on survival at all terrain sites. Grass species planting trials from 2014 also declined in survival between 2015 and 2016. Each of the five species planted had sites where individual plants survived, but overall survival and impact on natural colonization has been minimal.

Recommendations from 2016 observations include expanding *C. lenticularis* planting trials on low mud flat, as well as bluejoint reedgrass (*Calamagrostis canadensis*) on the Gun Creek Fan east and west. Live-stake cuttings should also be concentrated on upper drawdown and buffer zones only, and live-stake plantings using rooted stock of black cottonwood, trembling aspen, and Ponderosa pine should be carried out in the upper buffer zone of the Gun Creek Fan. We also recommend using native legumes and fertilizer in established planting sites. Maintenance with a focus on temporary irrigation is highly recommended for plantings, particularly in the upper drawdown zone. Finally, machine modifications to create beneficial microtopography features are recommended for trials from the lower mud flat through to the buffer zone.

There is no question from the trial results as monitored in 2016 that the drawdown zone around Carpenter Reservoir is a very hostile site for successful natural or treated vegetation establishment. Inundation and drought are primary factors in limiting natural vegetation establishment. Other factors including substrate texture, nutrient levels, as well as erosion by wind and water. Planting and revegetation trials are bypassing some issues with low seed inputs and early plant establishment to give species a head start on adapting to the challenges. *C. lenticularis* and *C. canadensis* remain the two herbaceous species showing the most potential for long-term establishment in the drawdown zone of Carpenter Reservoir.

OBJECTIVES, MANAGEMENT QUESTIONS and HYPOTHESES after 2015				
Study Objectives	**Management Questions**	**Year 2015 (MQ Status)**	**Management Hypotheses**	**Year 2016 (Hypothesis Status)**
1. To characterize and describe the riparian vegetation surrounding Carpenter Reservoir, assess changes over a 10-year period of time and infer relationships to water management.	To determine if implementation of the chosen operating alternative have had negative, neutral or positive impacts on the quality and quantity (species composition, biological productivity, spatial area) of the riparian area surrounding Carpenter Reservoir.	NOT YET ADDRESSED Baseline data collected in 2013. Monitoring to be repeated in year 10.	H_1: Implementation of the chosen alternative will not result in a reduction of riparian habitats in the area surrounding Carpenter Reservoir. $H1_A$: There is no significant change in the spatial extent of the vegetated area in the drawdown zone of Carpenter Reservoir. $H1_B$: There is no significant change in the species composition of the plant community in the vegetated area of the drawdown zone of Carpenter Reservoir. $H1_C$: There is no significant change in the relative productivity of the plant community in the vegetated area of the drawdown zone of Carpenter Reservoir.	NOT YET ADDRESSED

2. To assess impacts to the buffer zone vegetation in the event of a year of prolonged flooding >56 days.	To determine if implementation of the chosen operating alternative have had negative, neutral or positive impacts on the quality and quantity (species composition, biological productivity, spatial area) of the riparian area surrounding Carpenter Reservoir.	NOT CURRENTLY APPLICABLE	H_2 Incursions of less than 56 days into the reservoir buffer do not significantly impact riparian community.	NOT CURRENTLY APPLICABLE Baseline vegetation data was collected from permanent plots established in 2013. No significant incursions into the buffer zone for over 56 days have occurred to date. Slight incursions in 2015 prompt a closer look into origin of Hypothesis.

BRGMON-2 Status 2015

Study Objectives	Management Questions	Management Hypotheses	Year 2015 (Hypothesis Status)	Year 2016 report (Hypothesis Status)

3. To conduct evaluations of the BRGWORKS-1 program to assess the degree to which the planting program helps to establish natural re-colonization of the area from Tyaughton Lake Road Junction to Gun Creek Fan.	Does the implementation of a short term (5yr) intensive reservoir re-vegetation program result in benefits that were equal to or greater than that which were expected from implementation of the O3-2 operating alternative?	H_3. Implementation of extensive riparian planting for 5 years will provide the bases for continued natural re-colonization of the drawdown zone between the Gun Creek Fan and the Tyaughton Lake Road Junction. H_{3A}: Natural re-colonization is significantly greater at treated versus control locations. H_{3B}: There is no significant difference in the species composition of naturally re-colonizing species in planted versus control areas.	Monitoring of Year One BRGWORKS-1 re-vegetation trials was carried out in late summer 2014 and in June of 2015. Findings of initial year show relatively low rates of success in most trials, possibly related to the combined late project start in 2014, summer drought, and relatively low full pool of Carpenter in 2014 (643.95m). Control locations will be established in Year Two of re-vegetation treatment.	2015 water levels rose relatively early and quickly based on the average year since 2000. Control sites were established for comparative monitoring of vegetation cover development in the Low Mud Flat and Gun Creek Fan East terrain sites. 2013 transects were repeat monitoring as another method of control or reference for natural colonization in the target revegetation area. 2014 revegetation saw a significant drop in survival between 2015 and 2016 leaving very few test plots with viable plants. 2015 planting trials of C. lenticularis are surviving well as are some of the C. canadensis plantings, plants would benefit from soil building and or fertilization and irrigation early in growth. Cuttings trials have met with some small degree of success with lots of dieback from mechanical impact from reservoir Ice as well as abrasion by floating flotsam under periods of inundation. 2015 seeding trials with fall rye had limited number of GDD and plants attained relatively minor stage of growth before being flooded and killed. Higher elevation seeding trials of fall rye and native grass seed mixes did not appear to grow. Natural colonization of C. lenticularis from seed is observed in one low elevation area of the LMF however there is no evidence of multi year survival. There is no evidence of increased natural colonization in LMF control polygons vs those planted. Key difference is the presence of planted species in treated plots only.

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1.0 Introduction

BRGMON-2 has two monitoring components focused on studying the riparian vegetation in the drawdown zone of Carpenter Reservoir:

- Component 1: Monitoring the existing riparian vegetation in the Carpenter Reservoir drawdown zone, to be carried out in Year 1 (2013) and Year 10 (2022).
- Component 2: Monitoring the 5-year Re-vegetation project in the drawdown zone of the Carpenter Reservoir (BRGWORKS-1): Years 3 – 9 of BRGMON-2 (2015 to 2020).

The re-vegetation program under BRGWORKS-1 started in June 2014 and continued in 2015. The re-vegetation trials included planting and seeding trials carried out at various sites in the drawdown zone of Carpenter Reservoir near the town of Gold bridge, British Columbia (

Map 1) (Scholz, 2014). The year 2016 was the second year of monitoring Component 2 of BRGMON-2. Component 2 is focused on assessing and informing the BRGWORKS-1 re-vegetation trials in the drawdown zone of Carpenter Reservoir and addresses the following management question:

Does the implementation of a short term (5 yr.) intensive reservoir re-vegetation program result in benefits that were equal to or greater than that which were expected from implementation of the O3-2 operating alternative? [i](BC Hydro, 2012)[1]

The hypothesis to be tested under the BRGMON-2 Component 2 project is

> H3: Implementation of extensive riparian planting for 5 years will provide the bases for continued natural re-colonization of the drawdown zone between the Gun Creek Fan and the Tyaughton Lake Road Junction.
>
> > H3A: Natural re-colonization is significantly greater at treated versus control locations
> >
> > H3B: There is no significant difference in the species composition of naturally re-colonizing species in planted versus control areas

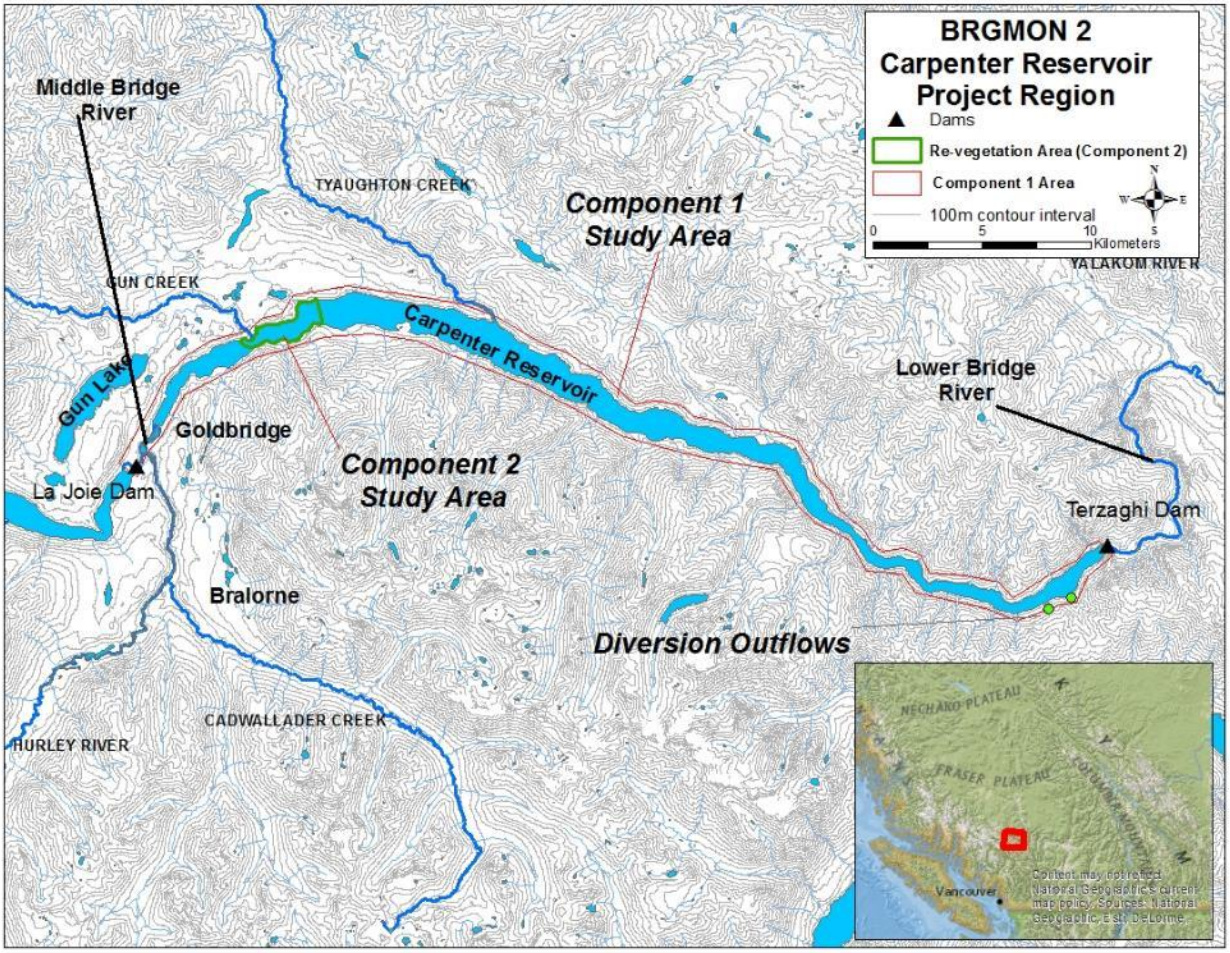
There is a second hypothesis included in the BRGMON-2 TOR that concerns water level inundation duration.

> H2: Incursions of less than 56 days into the reservoir buffer do not significantly impact riparian community.

This latter hypothesis is intended to trigger studies if and when these conditions are met[2]

[1] The BRGMON-2 TOR was revised in January 2017 but the current report is presented under the 2012 TOR that was applicable at the time of the monitoring in 2016.
[2] [2] Reservoir buffer zone is between 648m and 651.08m.

This report summarizes the methods and treatments done for BRGWORKS-1 in 2015, presents the annual inundation patterns in Carpenter Reservoir, summarizes the annual weather patterns during the vegetation's growing season, highlights successes and failures of treatments as of 2016, and makes recommendations for adjusting the treatments aimed at enhancing the riparian vegetation, in an adaptive management perspective.



Map 1. Targeted study areas for Components 1 and 2 of BRGMON-2.

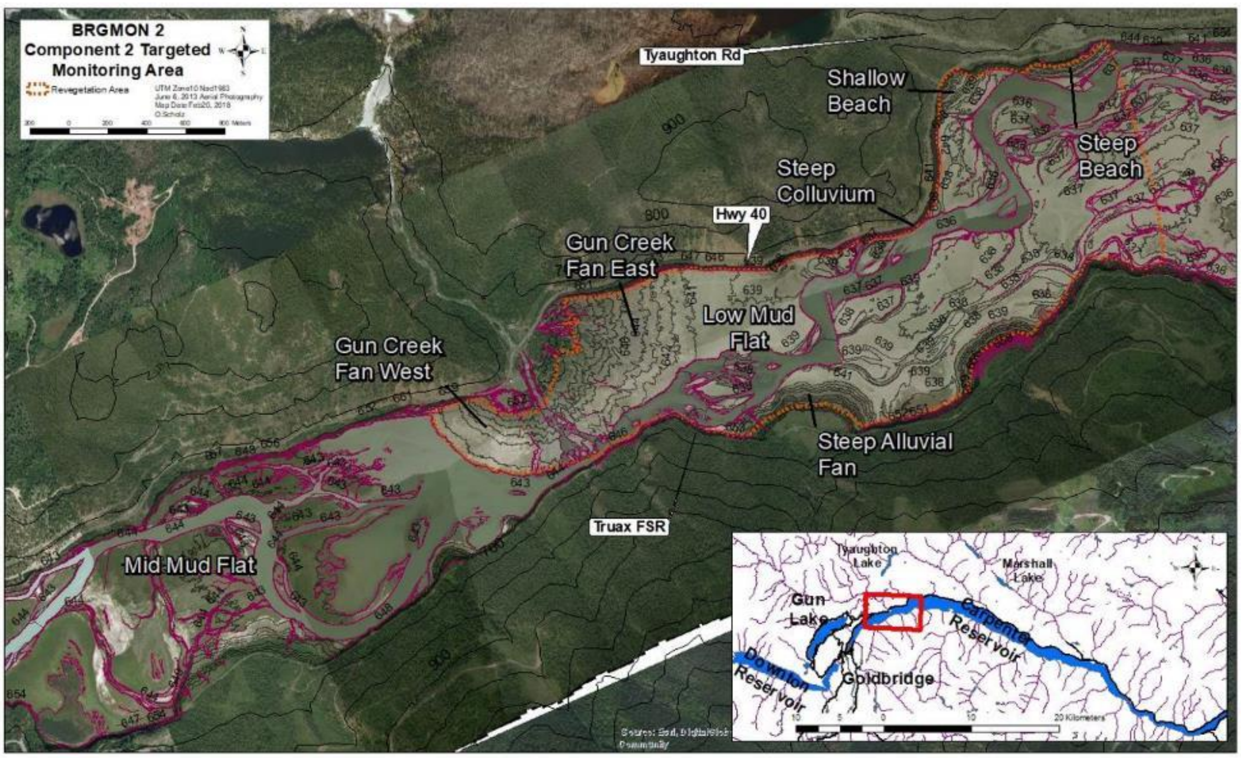
2.0 Background

The initial element (Component 1) of BRGMON-2 started in 2013. The drawdown zone in Carpenter Reservoir was stratified into terrain types and randomly sampled with permanent transects designed to characterize riparian vegetation around the reservoir. The terrain types were largely based on site-specific geomorphic conditions and elevation (Scholz and Gibeau, 2014).

Normal operations of the Carpenter Reservoir keep the drawdown zone above a low of 606.55 m Above Sea Level (ASL) and a targeted maximum of 648.00 m ASL (absolute capacity of the reservoir is achieved at 651.08 m ASL). The 3 m zone between 648.00 m ASL and

651.08 m ASL is considered a buffer zone which is to be inundated only when absolutely necessary. In an average year, elevations below 642 m ASL are exposed to the air for less than 50% of the growing season (Scholz and Gibeau, 2014). Based on analysis of historic drafting and inundation timing, it is highly unlikely that perennial native vegetation could survive below 640 m ASL. Restoration treatments under BRGWORKS-1 have been completed over a 10m vertical range, between 640 m ASL and 650 m ASL.

For Component 2 of BRGMON-2, at the landscape scale, five terrain types were targeted for re-vegetation trials under BRGWORKS-1 in 2014: Steep Beach (STB), Shallow Beach (SHB), Gun Creek Fan East (GCFE), Gun Creek Fan West (GCFW) and Steep Alluvial Fan (SAF) (Map 2). In 2015, treatments were expanded to include a sixth terrain type called the Low Mud Flat (LMF), located at lower elevation. Re-vegetation trials focused on seeding, planting rooted-container plants, and planting live-stake cuttings in 2014 and 2015.



Map 2. Targeted monitoring area and associated terrain types for Component 2 of BRGMON-2.

In 2015, the planting of rooted nursery-grown plugs and cuttings was expanded in areas of the STB, SHB, GCFE, and GCFW terrains. Treatments in the LMF terrain included seeding and planting rooted sedge plugs in 2015. Only trials of cuttings plantings were expanded at the SAF terrain in 2015. The six terrain types targeted for re-vegetation trials in 2015 represented the majority of the terrain found within the target re-vegetation area (Component 2). Re-vegetation work carried out for BRGWORKS-1 in 2015 is further summarized below; for more details, please see the 2015 annual report (Scholz, 2016).

Seeding trials

In 2015, the seeding trials for BRGWORKS-1 were completed in rectangular polygons to test the efficacy of using a tractor with a seeder attachment to plant linear strips on the LMF and GCFE terrains. Trials in LMF terrain utilized locally harvested seed of lakeshore sedge (*Carex lenticularis*) as well as fall rye (*Secale cereale*) (Seed 15-1 through Seed 15-06,Map 3). Locally harvested bluejoint reedgrass (*Calamagrostis canadensis*) and Canada wildrye (*Elymus canadensis*) were sown in polygons at higher elevations on the GCFE terrain (Map 4). Trials were also conducted to use fall rye as well as two grass seed mixes. The first seed mix was called a Lower Reservoir mix with foul bluegrass (*Poa palustris*) and bluejoint reedgrass (*Calamagrostis canadensis*), and the second was an Upper Reservoir mix with bluejoint reedgrass, foul bluegrass, slender wheatgrass (*Elymus trachycaulus*), ticklegrass (*Agrostis scabra*), and northern wheatgrass (*Elymus lanceolatus*).

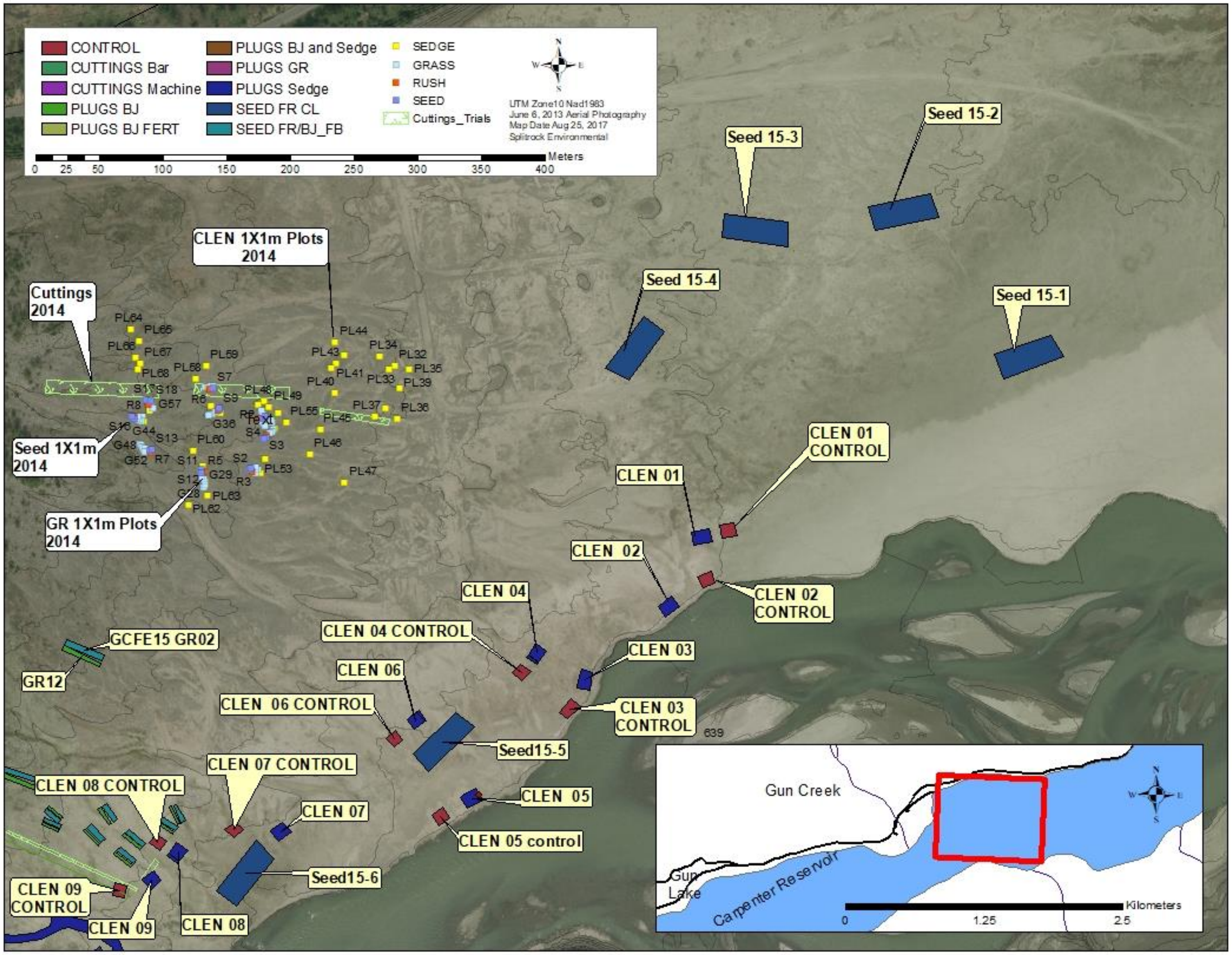
Plugs planting

In 2015, rooted plugs of container-grown stock from locally harvested seed were planted across polygons of the STB, SHB, GCFE, LMF and GCFW terrains. At low elevations on the Lower Mud Flat, nine roughly square polygons were established between 640m and 644m elevation, and control polygons were established alongside the planted sedge polygons in 2015. Higher up in the drawdown zone of the GCFE terrain, a large polygon ('little Creek') was planted with Lakeshore sedge along a feature that was identified as a natural seasonal overflow channel of Gun Creek (Map 4). Polygons were also established on the GCFE terrain where plugs of bluejoint reedgrass were planted parallel with seeding trials and controls (GR and GR 15 polygons on Map 4. Plugs of native grasses (bluejoint reedgrass, foxtail barley, foul bluegrass and Canada wildrye) were planted in polygons on the GCFW terrain (Map 5). Plugs of C. lenticularis and bluejoint reedgrass were planted in polygons distributed on the east and west ends of the Steep Beach terrain (Map 6). Plugs of C. lenticularis sedge and bluejoint reedgrass were planted in polygons at the Shallow Beach terrain type in 2015 (Map 7). A trial was also conducted using fertilizer tea bags with planted plugs at the SHB grass polygons. Fertilizer bags used were RTI Chilcotin Worm Blend 15-4-4).

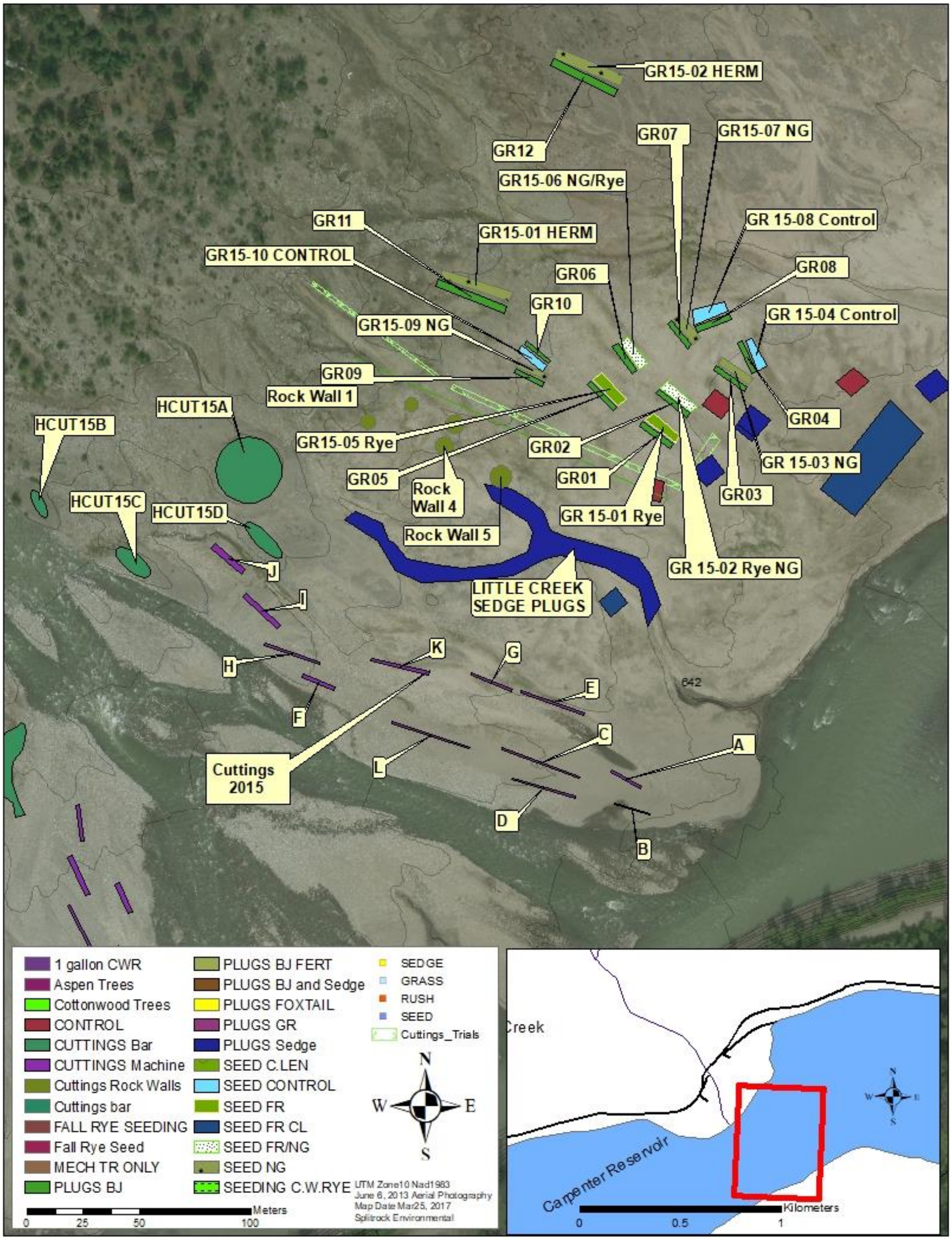
Planting of live-stake cuttings

Locally harvested live-stake cuttings of black cottonwood (*Populus balsamifera ssp. trichocarpa*) and willow species (*Salix sp*.) were also planted in 2014 and 2015. Two techniques were employed in planting the cuttings: hand-planting using steel planting bars and planting in trenches dug by an excavator. Twelve linear trenches were planted with cuttings on the GCFE adjacent to Gun Creek (Map 4). An additional seven polygons were hand-planted using steel bars on the GCFE. Small rock-wall features were hand-constructed around the cuttings hand-planted sites. Cuttings were also planted on the Gun Creek Fan West terrain with fourteen trenches excavated by machine, and one polygon in the upper elevations of the drawdown zone that was hand-planted (Map 5). Three polygons were hand-planted with cuttings at the STB. STB polygons were distributed at the east end, west end and center of the terrain (Map 6). One polygon area was hand-planted with cuttings in the middle of SHB terrain (Map 7**Error!**

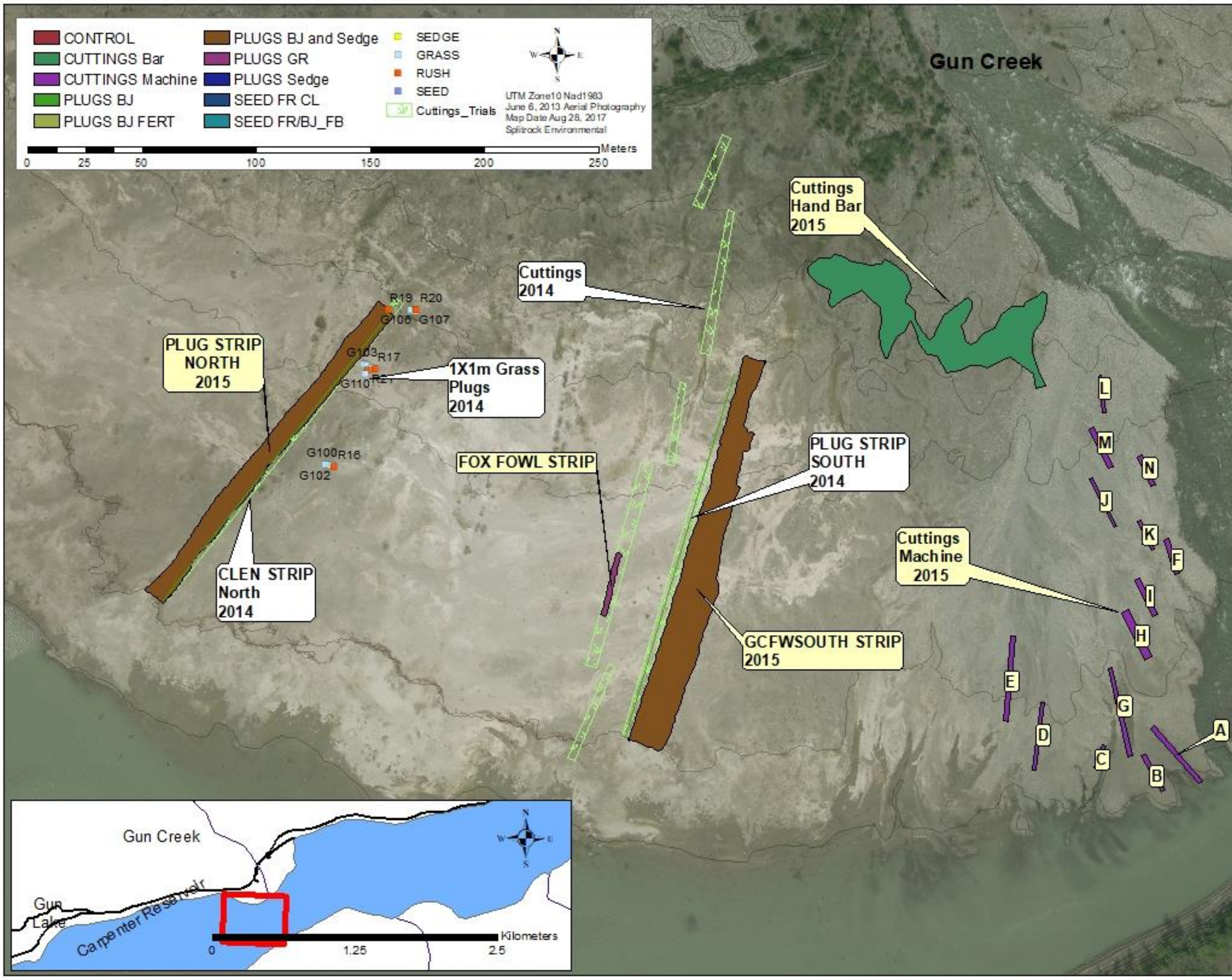
Reference source not found.). Finally, one polygon was hand-planted with cuttings at the SAF site, with a polygon situated along the banks of the tributary that currently flows through the west end of the fan (Map 8).



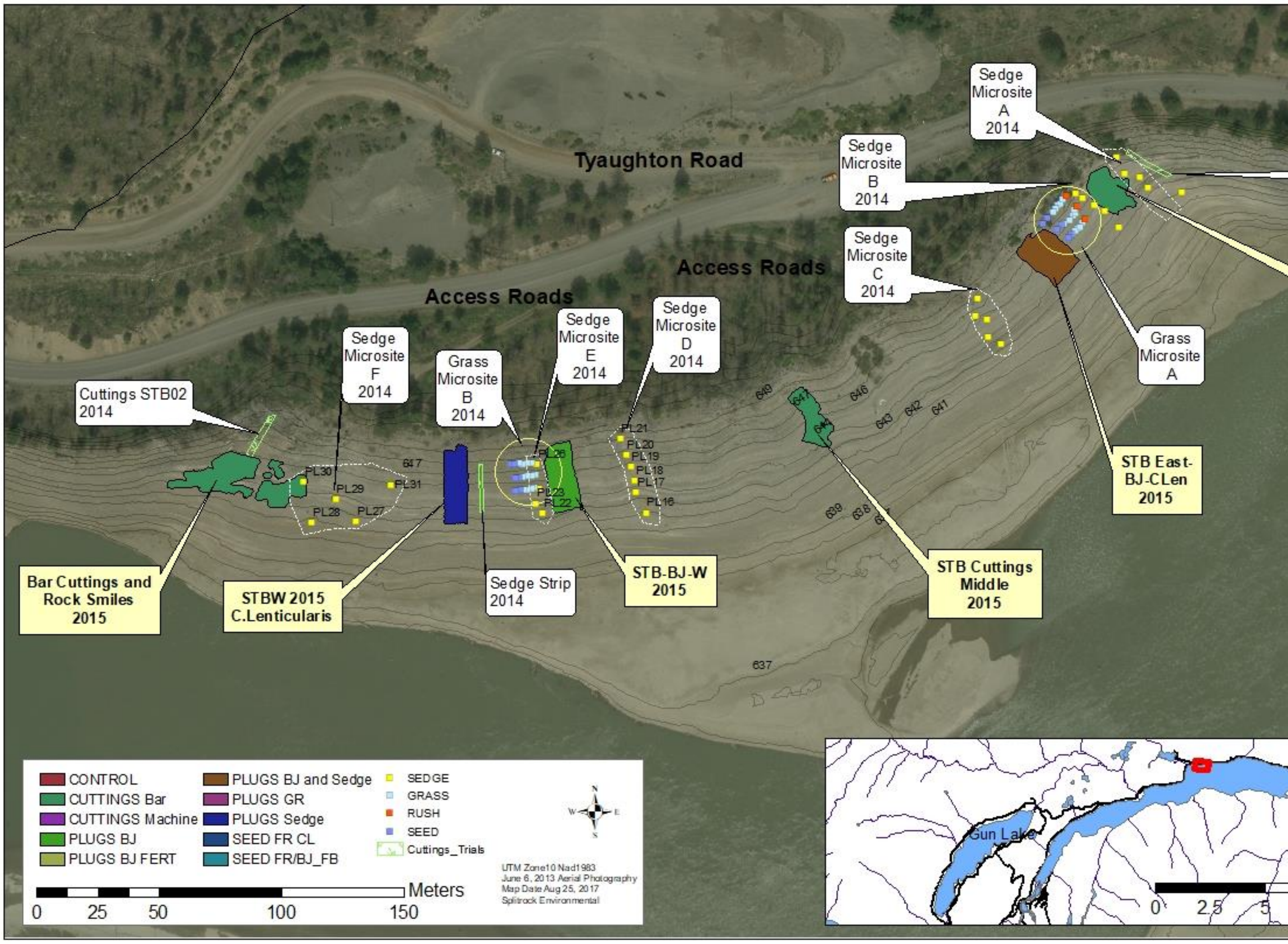
Map 3. Re-vegetation treatment polygons located across the Lower Mud Flat (LMF) terrain type in 2014 and 2015 (BRGWORKS-1).



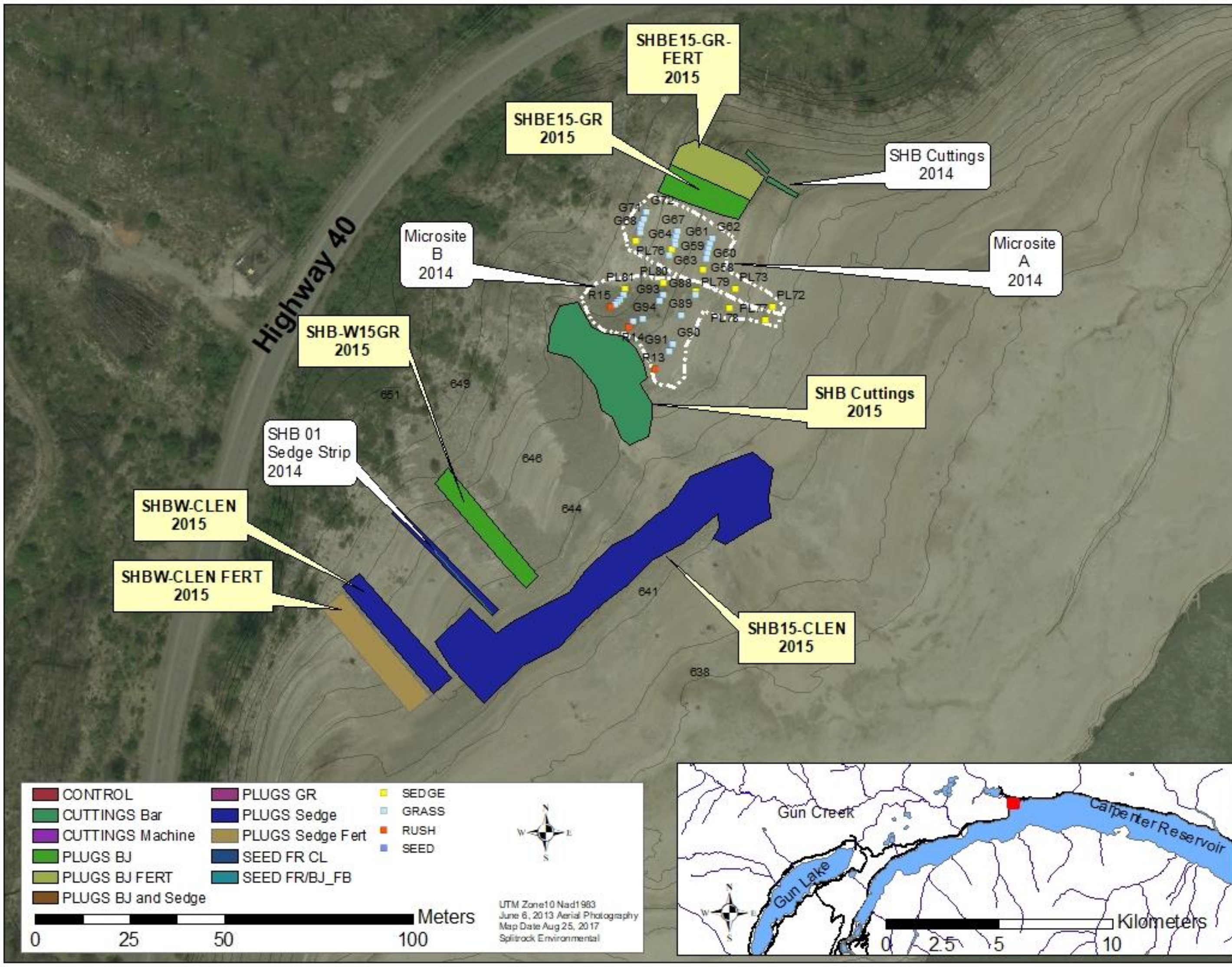
Map 4. Re-vegetation treatment polygons located across the Gun Creek Fan East (GCFE) terrain type in 2014 and 2015 (BRGWORKS-1).



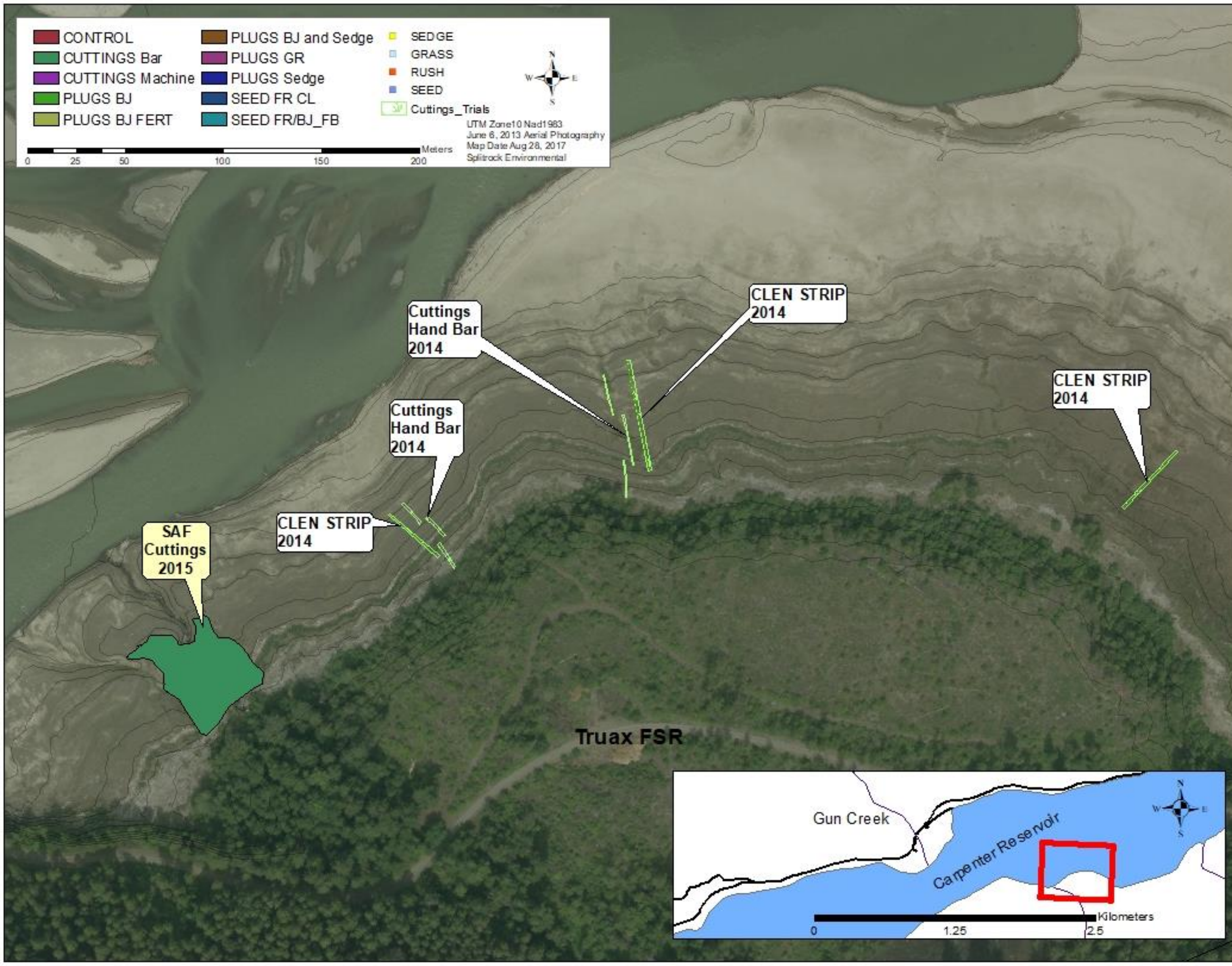
Map 5. Re-vegetation treatment polygons on the Gun Creek Fan West (GCFW) terrain type in 2014 and 2015 (BRGWORKS-1).



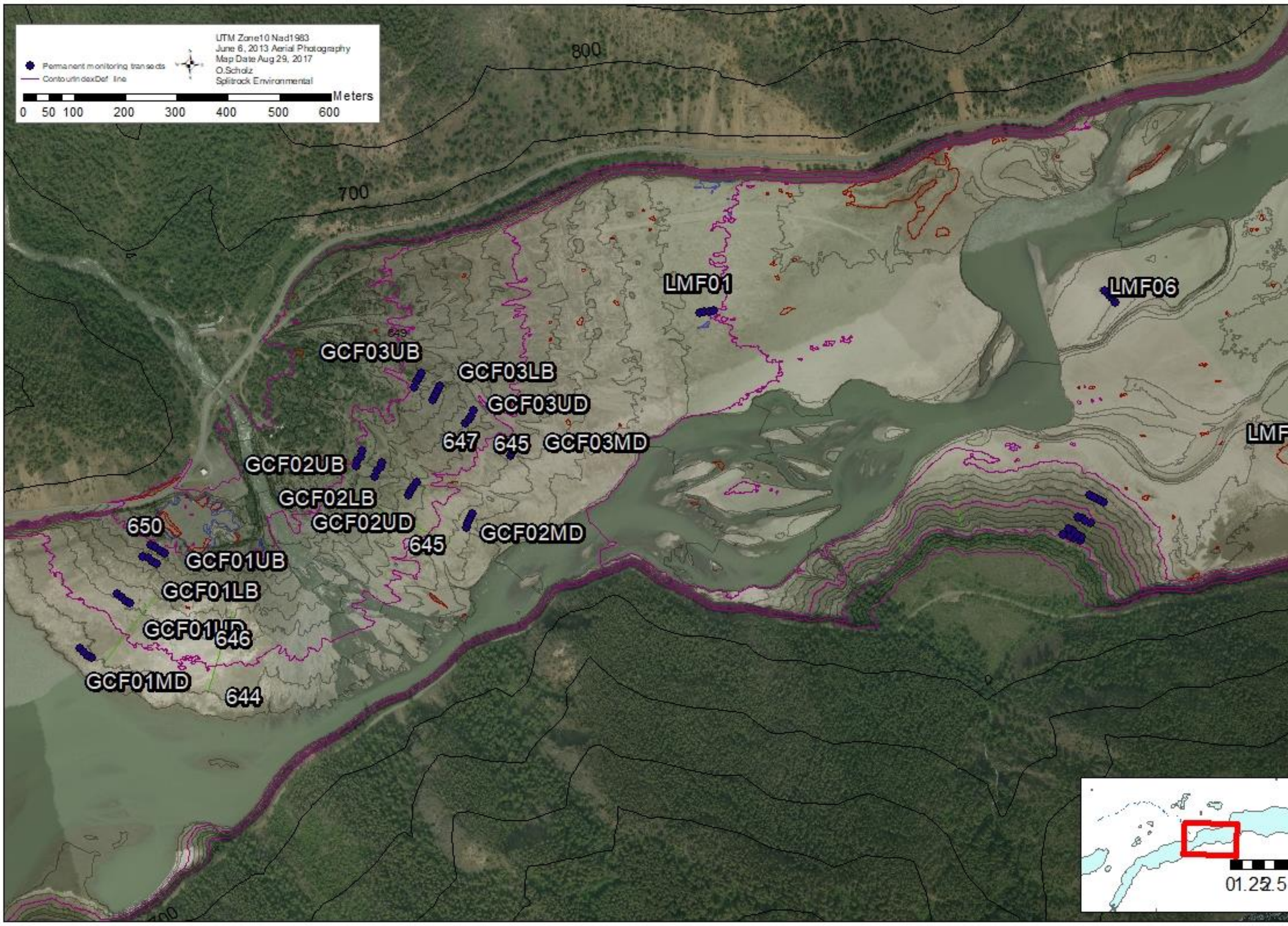
Map 6. Re-vegetation treatment polygons located across the Steep Beach (STB) terrain type in 2014 and 2015 (BRGWORKS-1).



Map 7. Re-vegetation treatment polygons located on the Shallow Beach (SHB) terrain type in 2014 and 2015 (BRGWORKS-1).



Map 8. Re-vegetation treatment polygons located on the Steep Alluvial Fan (SAF) terrain type in 2014 and 2015 (BRGWORKS-1).



Map 9. Permanent transects monitored in 2016 as control plots for treatments performed in 2014 and 2015 (Component 1, BRGMON-2).

3.0 Methods

Key approaches employed in the first three years of the project tested the introduction of selected perennial native herb, shrub and tree species into targeted macro- and micro-sites in the drawdown zone. Site characteristics, especially elevation, were identified as key variables to test, along with choice of species and method of revegetation (cuttings, rooted plants, seed). Other key variables affecting revegetation success include annual climate conditions, variability in reservoir inundation regime, and disturbance by wildlife and by human activities. The field program in 2016 included assessing the re-vegetation trials established in 2014 and 2015 for BRGWORKS-1 (Component 2). The monitoring in 2016 was also extended to include monitoring of a selection of the permanent transects established under Component 1 of

BRGMON-2 in 2013. Permanent transects were monitored as control plots from which to infer natural background vegetation colonization and growth throughout the study area of Component 2 (Map 9). Additional trials were also conducted for BRGWORKS-1 in 2016, and those treatments will be monitored by BRGMON-2 in 2017.

3.1 Water levels and weather

The water levels in Carpenter Reservoir are monitored by BC Hydro Power Records who issue daily reports. Water level data were collated and are presented in a graph showing the water levels for the study areas in 2016 as well as the levels from previous years. In addition, the average water level from 2000 to 2016 was graphed to place the current year in context of water level management patterns since the inception of the WUP. In addition to water levels, local weather patterns for 2016 are presented based on data provided by the Ministry of Forests Range and Natural Resource Operations, at the Fire Zone weather station located on 5 Mile ridge. The 5 Mile ridge station is within 5 km of the monitoring sites for Component 2 of BRGMON-2. Precipitation and temperature were summarized for 2016, and growing degree days (GDD) were computed based on the BC government range readiness approach, where after snow-free conditions and no sooner than March 15th there must be five consecutive days when the daily average temperature exceeds 0°C before growing degree days begin to accumulate (Fraser, 2006). GDD are calculated using the conservative approach of base temperature of 0°C, and by the formula (daily Max. + Daily Min.)/2 - 0°C. The base temperature is the temperature below which plant growth is impeded and was presumed to be 0°C (as in range management). Plants do not grow any faster when temperatures are over 30°C, and therefore, the mean daily temperatures were filtered to cap the high temperature days at 30°C.

3.2 Monitoring the trial plots from 2014

The trial plots from 2014 were relocated using GPS coordinates and, since plots were marked with a metal pin in the center of each plot, a metal detector was used to locate plots hidden because of buried pins. At each location, 1X1 m plot frames were placed over the plot center pins to carry assessments for seedlings and planted plugs. Data collected in each plot included:

- Date,
- GPS waypoints,
- Unique Plot number,
- Species planted,
- Number of planted plants,
- Number of plants observed surviving,
- % cover of planted vegetation,

- % cover of all vegetation,
- Average height of planted plants,
- Average base width of planted plants,
- Plant vigor, (5 classes subjective rating, 0=dead, 1= poor, 2= fair, 3= good, 4=excellent)
- Utilization, (present use for browse or forage 0, 1=1-15 %, 2= 16-36%, 3=36-65%, 4= 66-80%, 5=>80%)
- Vegetative phenology of planted plants, (0=without shoots above ground, 1=shoots without unfolded leaves, 3=first leaf unfolded, 4=several leaves unfolded, 5= almost all leaves unfolded, 6=plant fully developed, 7=stem and or first leaves fading, 8= yellowing up to 50%, 9=yellowing over 50%, 10=dead)
- Generative phenology of planted plants, (0=without blossom buds, 1=Blossom buds recognizable, 2= Blossom buds strongly swollen, 3=shortly before flowering, 4=beginning flowering, 5=in bloom up to 25%, 6= in bloom up to 50%, full bloom, 8=fading, 9=completely faded, 10=bearing green fruit, 11=bearing ripe fruit, 12=bearing overripe fruit, 13=fruit or seed dispersal).
- Number of plants producing seed,
- Wildlife sign,
- Wildlife species,
- Pin height relative to the ground level,
- Extra notes,

Plot data was digitally recorded in the field using ipads and software made specifically for the monitoring project via the Doforms © software. Photographs were taken for each plot from the horizontal and vertical perspectives. A meter board was placed at the top (upslope) center of each plot frame of each picture (Figure 1). Collected data was transferred into Microsoft Excel for storage and analysis.

Similar data were recorded to monitor success of plantings of live-stake cuttings over all of the areas planted.

Figure 1. Example of the photo-monitoring performed at each plot.

3.3 Monitoring the trial polygons from 2015

The treatment polygons established in 2015 were sampled in two ways in 2016: by using 1mx1m plots and by a general assessment of survival in entire polygons with notes on plant vigor. Sedge polygons in LMF terrain were sampled using 1X1 m plots and the same data collected as for the 2014 trials. Five plots were randomly placed to sample treatment success within both treatment and control polygons in LMF terrain (CLEN01-CLEN08, Map 3). One overhead image was taken for each plot to provide photo-monitoring. Sampling with 1X1 m plots was also used to monitor bluejoint reedgrass plantings and seeding polygons in the GCFE terrain (GR and GR 15 plots, Map 4) as well as in the SHBE terrain (SHBE GR, Map 7).

Seeding trials in the LMF and GCFE terrains were sampled using 1X1 m plots (Seed Plot 01 through 06, Map 3). In the LMF terrain, transects were stretched for the length of the 50 m polygons and sample plots were placed at 10 m intervals. Sampling of seed plots in the LMF was carried out to detect if seeding trials were promoting sedge colonization. In the case of GR and GR15 plots, data was gathered as in the 2014 trials.

Success of planting of live-stake cuttings and other plugs was assessed with live tallies per polygon area over all areas treated.

3.4 Monitoring the trial polygons from 2016

During late spring of 2016, treatments consisted of planting of large polygon areas on LMF terrain for BRGWORKS-1. Under BRGMON-2, monitoring in 2016 included sampling of several polygons treated for the first time in 2016 for BRGWORKS-1 program. Sampling was carried out in June prior to inundation. The sampling was carried out in a similar way as for the 2015 trials (see 3.3).

3.5 Analysis of monitoring data

Survival, cover of planted and total vegetation, and height of vegetation were summarized per treatment (plug, seeds or live-stake cuttings), per species planted, year, elevation and terrain types, as relevant.

The significance of the differences in survival, cover of planted and total vegetation, and height of vegetation was tested when relevant (i.e. when the sample size was big enough) with a generalized linear mixed model of the form: log (survival + 0.05) ~ Year + Elevation + Terrain, random= ~1|plot number, method = "ML", which allowed for an explicit consideration of the repeated nature of the data by including the plots as a random effect (Zuur et al. 2011). The dependent variables were log-transformed to ensure that models were fitted to a positive scale. The value of 0.05 (or half the smallest value in the specific dataset, as a rule of thumb) was added to compute the log of samples with no values. Year and elevation were standardized prior to their inclusion in the models since they were of different dimensions and units (Legendre and Legendre 2012). Diagnostic plots were reviewed to determine how the models aligned with fitting assumptions. Results are summarized in appendices as coefficient plots, which show the value of the regression coefficients (effect size) for each explanatory variable, along with a measure of their variation (± 2 SE with confidence interval). The width of the confidence intervals gives an indication of the confidence in both the magnitude and sign (positive or negative) of the coefficient. Intervals that cross the 0 line indicate lack of confidence in the effect described by the coefficient. The significance each variable included in the model was tested via a wald test, which approximates the likelihood ratio test that tests each coefficient against the full model containing all coefficients.

All figures and models were produced in the R language version 3.4.4.

4.0 Results

4.1 2015 Hydrograph

The water levels in 2015 were, for the most part, well above average for much of the growing season (

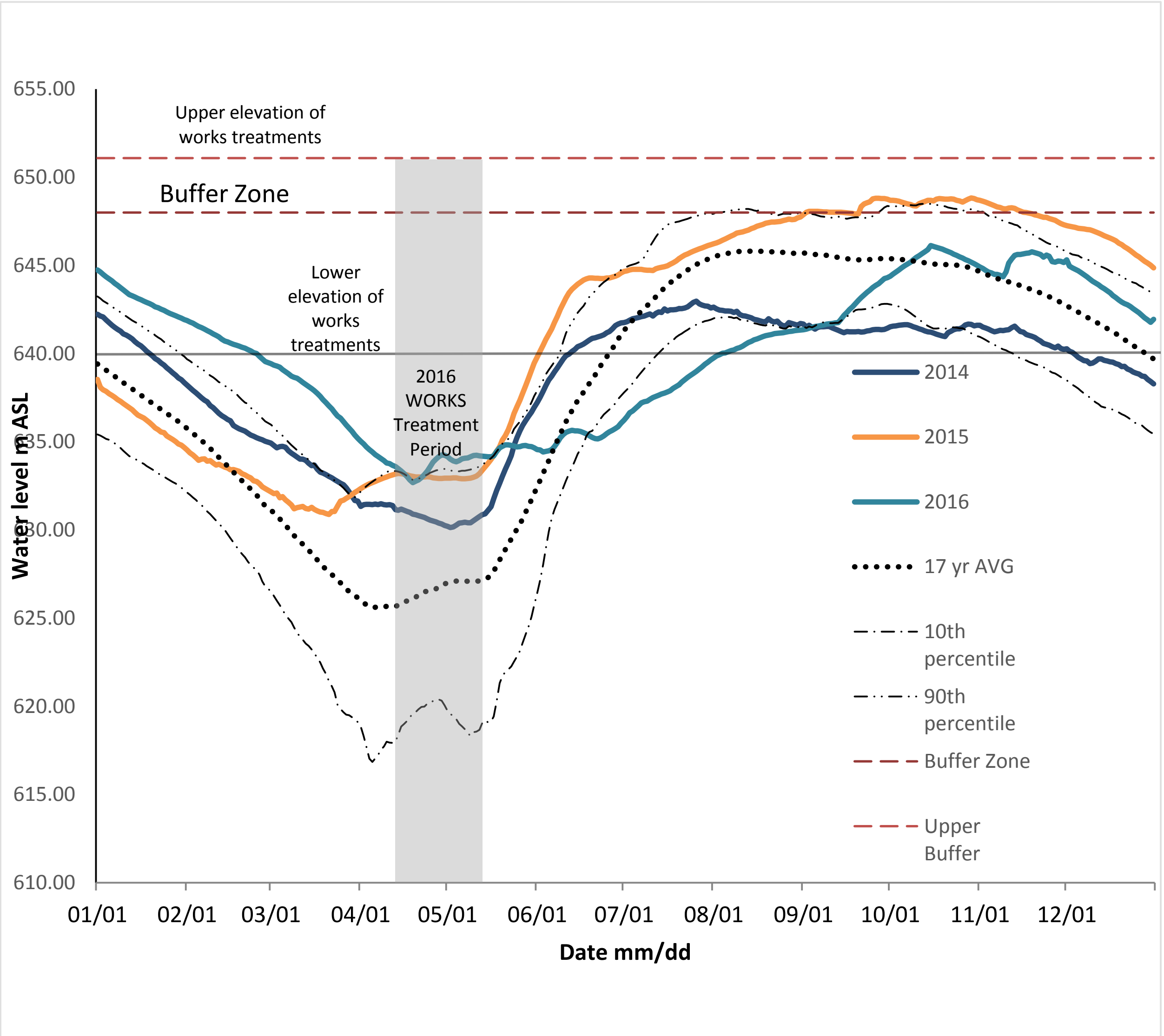


Figure 2). The low pool levels in 2015 remained relatively high at 630.8 m ASL, which is approximately five vertical meters above the 16-year average low pool. Water levels rose earlier than in most of the years since 2000. The treatment sites of 2015 situated at the lowest elevation were inundated by the reservoir as early as June 02nd, 2015. Treatments completed in 2015 for BRGWORKS-1 occurred at upper elevations through to June 10th 2015. Water levels rose to peak just above 648 m ASL on September 02nd 2015, which is the low elevation of the riparian buffer zone. The full pool levels hovered around the lower end of the buffer zone, peaking at 648.78 m ASL several times in October 2015. Water levels were at the lower edge of the buffer zone (648.00 m ASL as defined in the Section 87 and 88 Order dated March 30,

2011) for 14 days then rose to be at least 0.15m into the buffer zone for 55 days before dropping to within 0.10 cm of the lower elevation of the buffer zone. In total, full pool levels were above 648 m for 71 days in 2015.

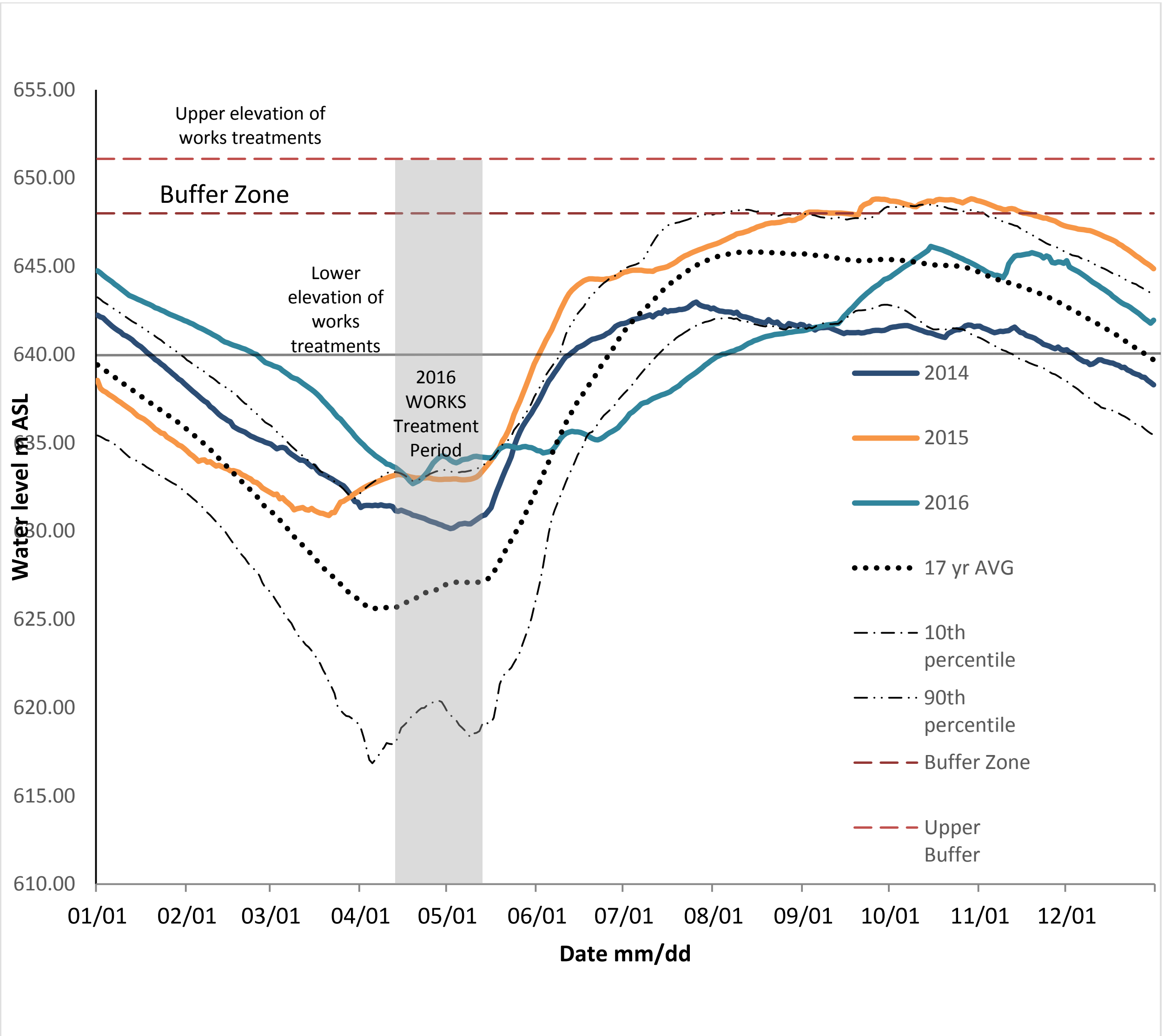


Figure 2. Hydrograph showing water levels in Carpenter Reservoir in 2014, 2015, and 2016.

4.2 Weather patterns in 2015

The date for the inception of the growing season was based on data collected at the 5-mile weather station as well as on site observation. The calculated average daily temperatures were above zero degrees for 10 days prior to March 15th and for 5 days post March 15th. A field tour of the site was made on March 19th 2015 as part of a pre-season assessment of the site conditions to assist in planning for the beginning of the 2015 BRGWORKS-1 season. Some observations from that day were that most of the ice and snow had melted from the Low Mud flats and the Gun Creek Fan. Small patches of ice did persist in locations on the mud flat and very young germinating seed were observed out on Gun Creek Fan East during scoping on March 19th (Figure 3). Based on these observations and an analysis of the weather station data it was estimated that March 15th was a reasonable date to begin to tabulate growing degree days for 2015.

Treatment sites at low elevation received between 738.4 and 987.7 accumulated growing degree days (AGDD) while mid elevation sites (645-647 m ASL) received between 1594 and 2109 AGDD in 2015 (Figure 4, Figure 5). Upper elevation sites (648-651 m) received between 2437 and a full growing season of 2999 AGDD that was experienced by vegetation located throughout most of the buffer zone. In comparison, in 2014, there were 2061 AGDD from March 15th through October 30th for elevations above 643m. The reservoir peaked at 643 m ASL in July 2014, leaving all but a few of the 2014 trials unaffected by inundation (Scholz and Gibeau, 2015).

During the growing season in 2015, 265.2 mm of precipitation was recorded in the re-vegetation study area over 73 days (Figure 4). Fifteen of those days had precipitation measured at greater than 5 mm. The total precipitation for the year was 437.6 mm. As a comparison, 262 mm of precipitation was recorded throughout the growing season in 2014, including 71 days with precipitation and 17 days with precipitation over 5 mm.

Figure 3. Example of germinating herbs and early sign of growth on the Gun Creek Fan East site on March 19, 2018

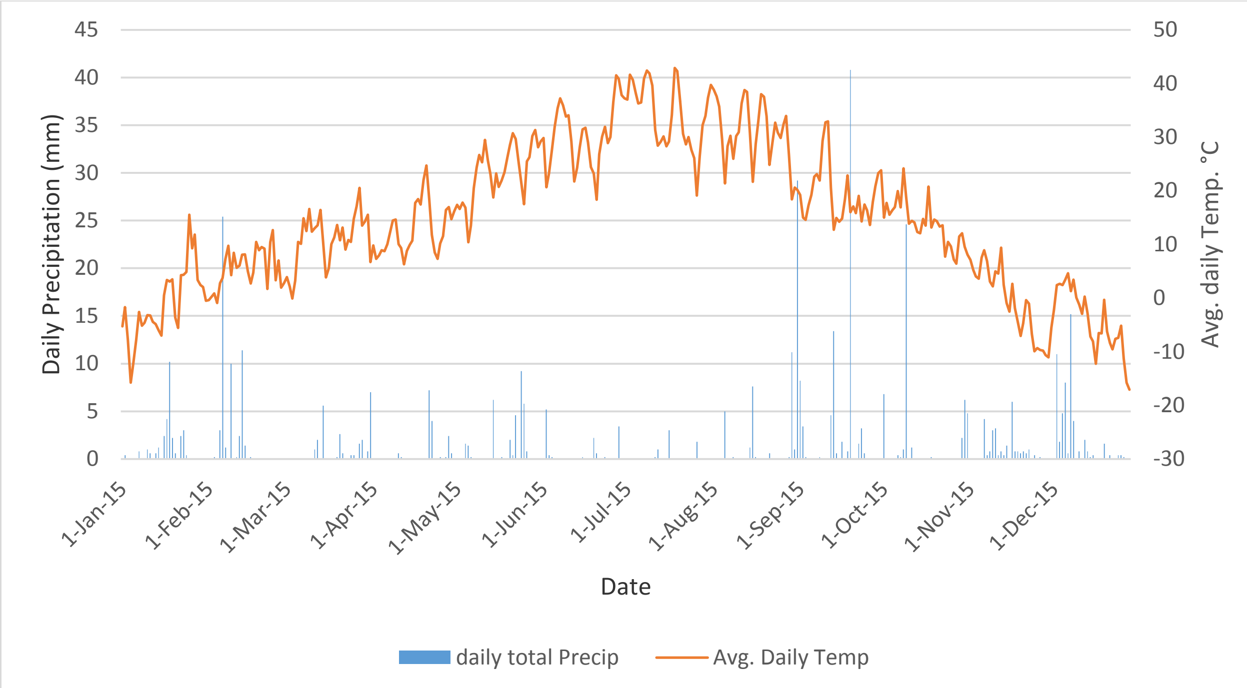


Figure 4.   Meteorological data in 2015 from the weather station at 5-mile ridge (total daily precipitation and average daily temperature).

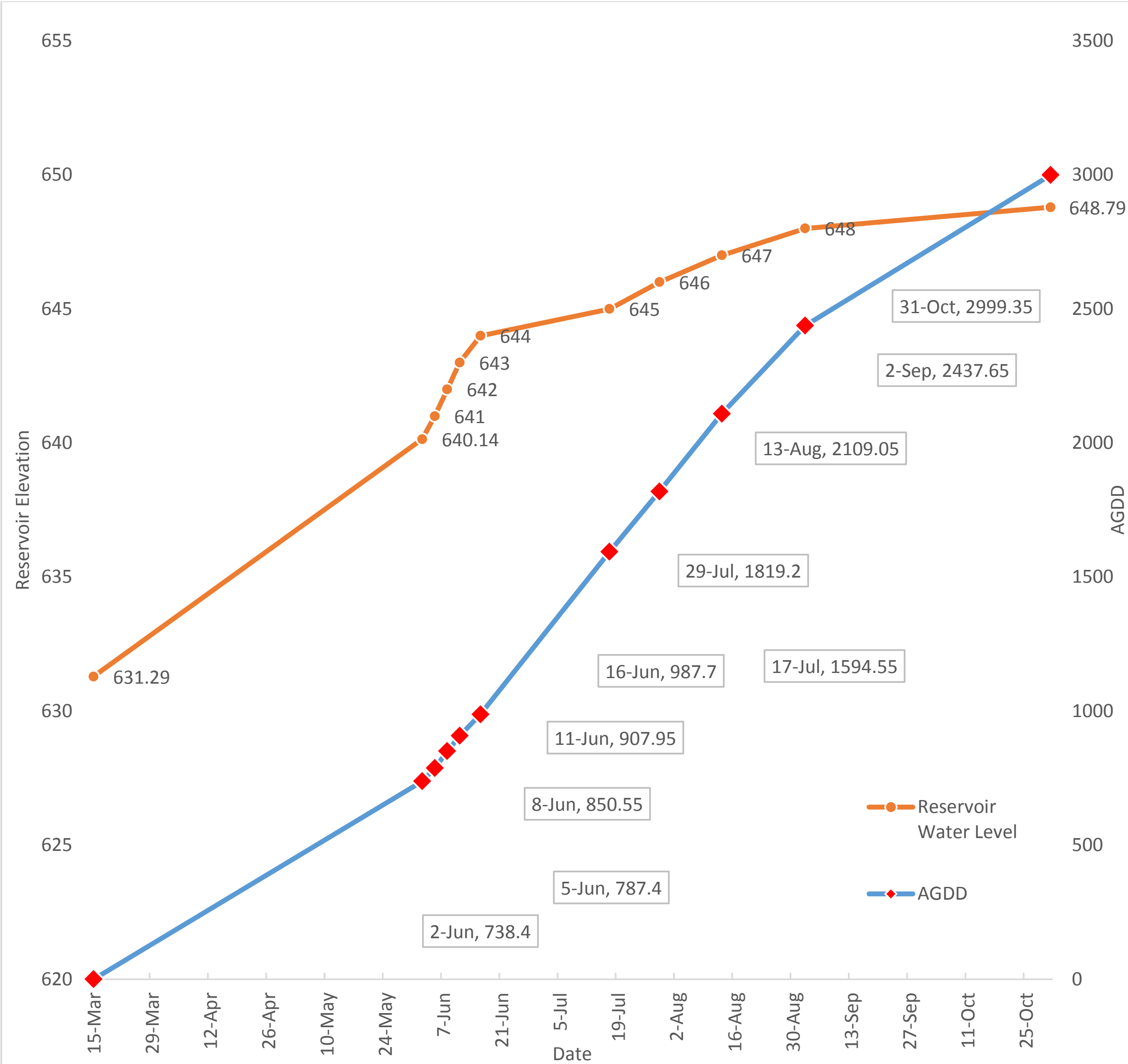


Figure 5. Accumulated growing degree days (AGDD) for 2015 along with the water levels in Carpenter Reservoir.

4.3 Monitoring 2014 and 2015 WORKS-1 Treatments

Monitoring conducted for the BRGMON-2 in 2017 focused on measuring treatment success from the first two years of WORKS-1 program by looking at survival and cover of planted and seeded native species, as well as total vegetation cover in treatment plots and polygons. Other variables monitored included plant vigor, growth, and natural revegetation.

Monitoring in 2016 also included sampling control sites to assess the following hypothesis:

H3A: Natural re-colonization is significantly greater at treated versus control locations

H3B: There is no significant difference in the species composition of naturally re-colonizing species in planted versus control areas

We did not emphasize the origin of re-colonizing species during monitoring in 2016 (i.e. whether or not species were native or exotic). Control sites established in 2015 were monitored in 2016, as well as 18 of the original BRGMON-2 permanent monitoring transects first sampled in 2013 that occurred within the revegetation trial region. The permanent transects were monitored to serve as control and reference sites for species composition, cover and distribution within the revegetation trial area. The results of monitoring of the 18 permanent plots will be reported as part of the reference monitoring in the mid-term comprehensive report planned for 2018.

4.3.1 Results of monitoring of the 2014 trial plots

Re-vegetation trials in 2014 focused on 1X1 m plots distributed across terrain types and elevations. A key target of the WORKS-1 effort in 2014 was to test the survival of select species at each terrain types and microsites (Scholz, 2014). A total of 121 of the 231 1X1m plots established in 2014 trials were monitored in 2016.

4.3.1.1 Survival and condition of lakeshore sedge (C. lenticularis)

Survival was similar between the two microsites in Shallow Beach (SHB) terrain and declined between 2015 and 2016 at low elevations and high elevations (Figure 6). Average height of vegetation was either constant between years or increased slightly in 2016. Cover of planted and total vegetation was generally low (< 16%), and decreased in 2016 at 644 m, 645 m and 648 m, but was higher in 2016 at mid elevations (646-647 m). The vigor for surviving plants was rated fair to good at both microsites.

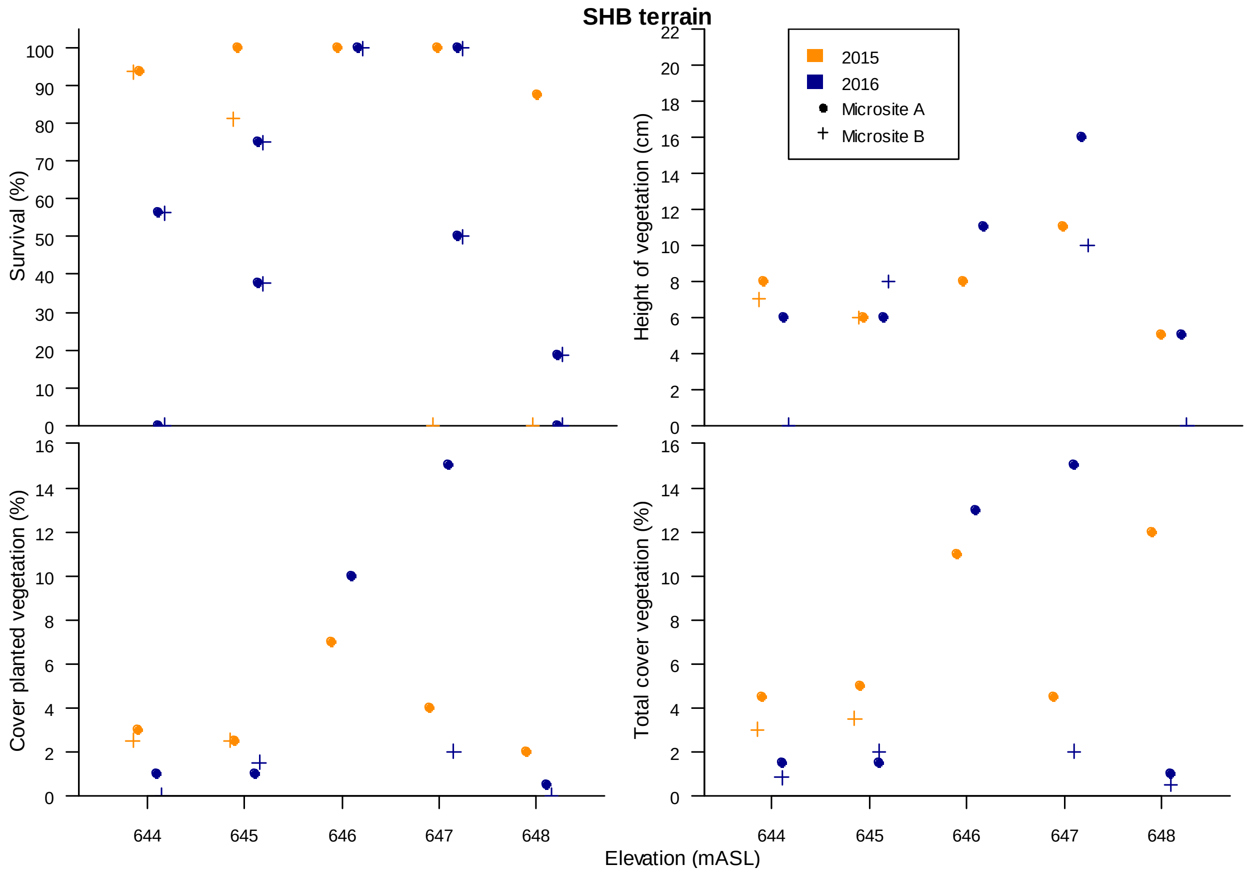


Figure 6. Variation in survival of CLEN plugs (%), height of vegetation (avg., cm), cover of planted vegetation (%), and total cover of vegetation (%) in 2015 and 2016 per elevation in SHB terrain types (n=10 plots in 2 microsites).

The strip of sedges planted in 2014 at the SHB was monitored for survival and vigour in 2016. Plants in the strip had survived well into the third growing season. Plants growing at the lower elevations of the strip between 644 and 645 m were observed having vigor between fair and good with 4 plants notably in excellent condition. All plants at higher elevations 645-648m were noted as having fair to poor vigour.

In STB terrain, survival generally declined at all 2014 trial microsites between 2015 and 2016, and cover of planted vegetation was very low (<5%) (Figure 7). Total cover of vegetation increased in some microsites over time.

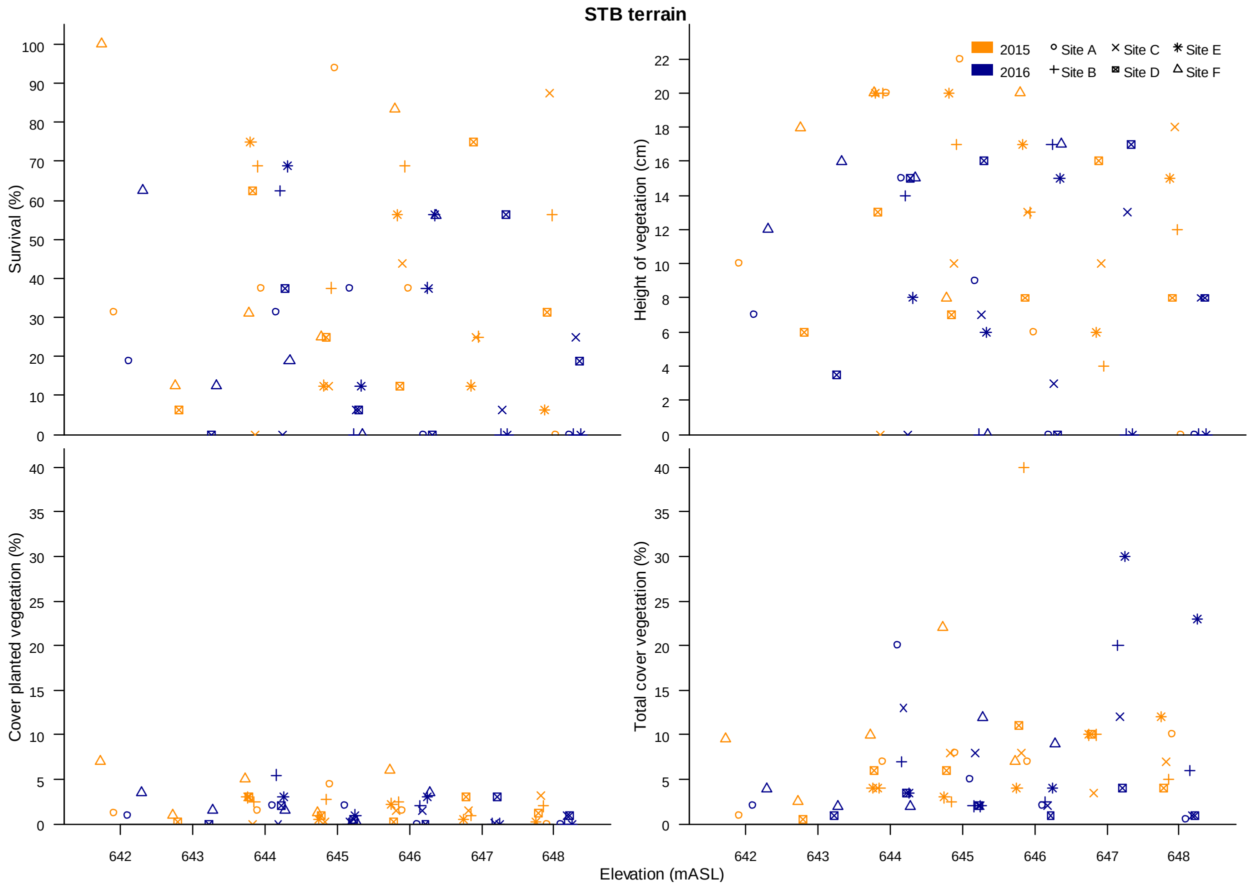


Figure 7. Variation in survival of CLEN plugs (%), height of vegetation (ave, cm), cover of planted vegetation (%), and total cover of vegetation (%) in 2015 and 2016 per elevation in STB terrain types (n=31 plots in 6 microsites).

The strip of C. lenticularis plugs planted in 2014 at the Steep Beach site (Map 13) was monitored for survival and establishment, and over half the planted plants were observed to be surviving (59%). Plants in the strip were classified with fair to good vigour ratings.

Survival in GCFE terrain was generally very low, especially at and above 646 m, and declined further in 2016 (Figure 8). Consequently, not surprisingly, height and cover of planted vegetation were also very low, as was total cover of vegetation.

A strip of C. lenticularis was also planted at the GCFW terrain class in 2014 (Map 10). A complete survey of surviving plants indicated a 10% survival through to 2016. The highest concentration of surviving plants was found between 645 and 645.5 m elevation (Figure 9).

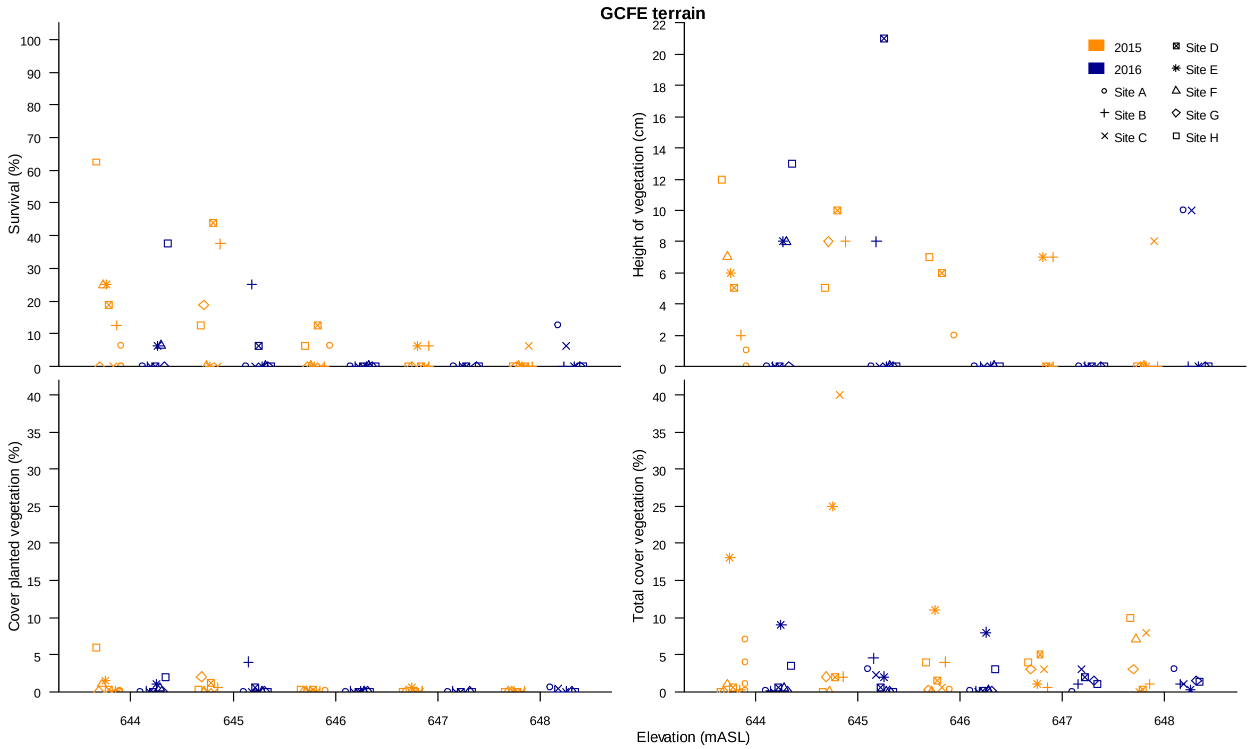
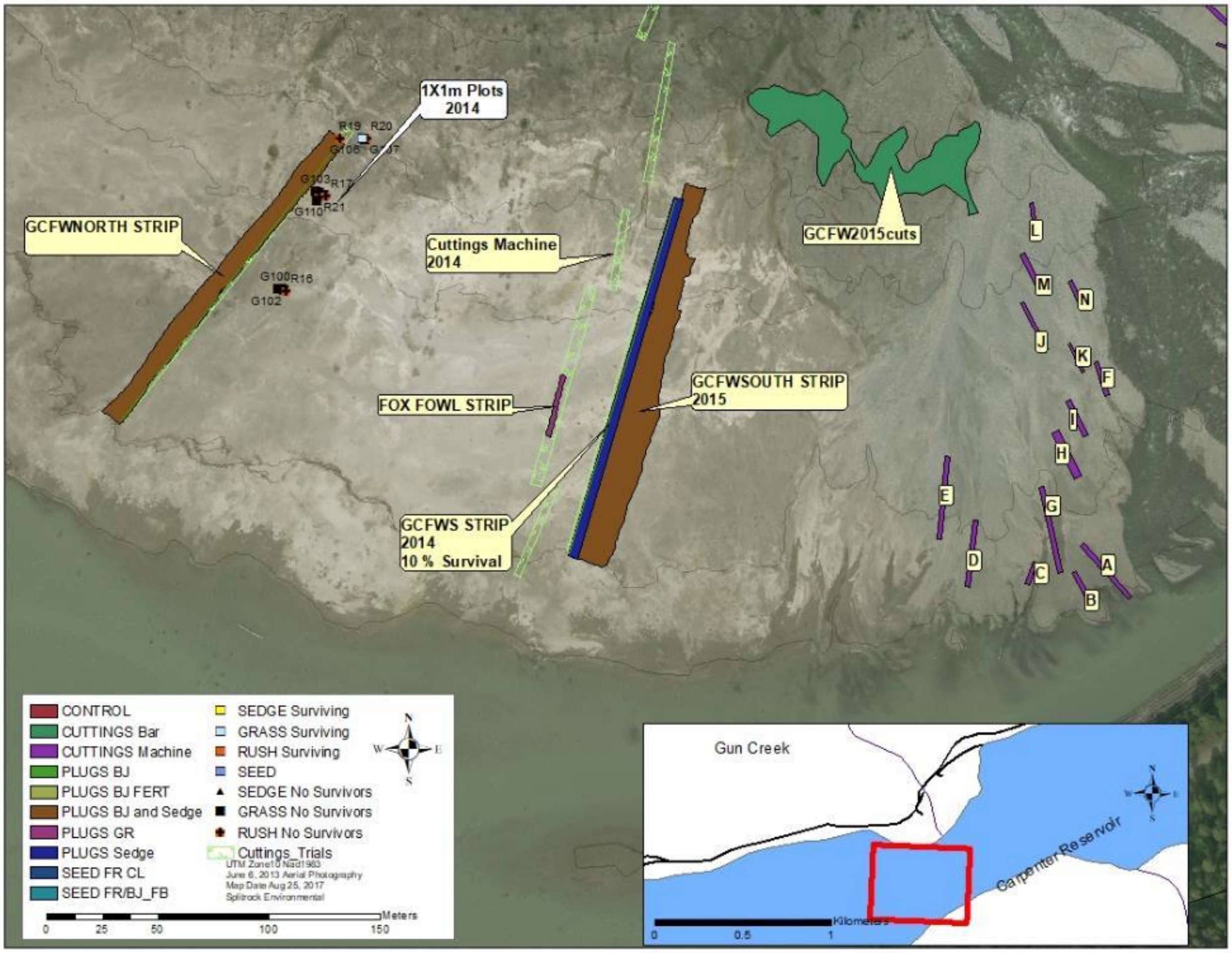


Figure 8. Variation in survival of CLEN plugs (%), height of vegetation (ave, cm), cover of planted vegetation (%), and total cover of vegetation (%) in 2015 and 2016 per elevation in GCFE terrain types (n=41 plots in 8 microsites).



Map 10. Treatment polygons in Gun Creek Fan West.

Figure 9. Surviving plants in the strip of C. lenticularis around 645 m ASL in Gun Creek Fan West in 2014.

Generalized Linear Mixed Models (GLMM) suggest that, all else being constant, year had a large significant negative effect on survival (i.e. survival decreased by 47% on average in 2016 as compared to 2015), height of vegetation (-57%), cover of planted vegetation (-67%), and total cover of vegetation (-49%; Table 1, Figures A to D in Appendix A). Elevation only had a significant negative influence on height (-16%) and cover of planted vegetation (-26%), but a barely significant (at $\alpha < 0.1$) decline of 10% in survival was noted for each increase of 1m in elevation (Table 1). All else being constant, survival, height of vegetation, and cover of planted or total vegetation were minimal in GCFE terrain, but survival increased by 10% and cover of planted vegetation increased by 70% in SHB as compared to GCFE terrain. Increases in survival, height, or cover of vegetation were less important between STB and GCFE terrains (Table 1). Importance of time was about twice as large as that of elevation, in decreasing survival, height of vegetation, and total cover of vegetation. Diagnostic plots were reasonable except for a skew due to the large presence of 0s (response variables were log-transformed).

Table 1. Summary of GLMM regression models with partial (standardized) regression coefficients for each explanatory variable, along with their significance and effect size. The standard deviation for year was 0.502 for all response variables (except height of vegetation, where it was 0.49989 due to the presence of missing data), and 1.563 for elevation (1.5987 for height of vegetation). Significance level α was assumed to be 0.1.

Response variable	Explanatory variable	regression coefficient	t	p-value	Effect size (per unit of X)
Survival	Year	-0.32	-6.1	0	-47%
	Elevation	-0.16	-1.8	0.08	-10%
	GCFE (intercept)	1.6	12.15	0	4.95%**
	SHB	2.4	7.8	0	10.7%*
	STB	1.4	6.9	0	4%*
Height of vegetation	Year	-0.42	-4.95	0	-57%
	Elevation	-0.27	-2.3	0.026	-16%
	GCFE (intercept)	0.36	2.07	0.042	1.4%**
	SHB	1.41	3.67	0.0004	4.1%*
	STB	1.43	5.7	0	4.2%*
Cover of planted vegetation	Year	-0.56	-4.2	0.0001	-67%
	Elevation	-0.46	-2.3	0.027	-26%
	GCFE (intercept)	-3.98	-13.6	0	0.02%**
	SHB	4.25	6.3	0	70%*
	STB	3.1	6.9	0	22%*
Cover of total vegetation	Year	-0.34	-3.3	0.002	-49%
	Elevation	0.24	--	--	--
	GCFE (intercept)	-0.96	-3.5	0.0008	0.38%**
	SHB	2.05	3.2	0.002	7.8%*
	STB	2.6	6.1	0	13.5%*

* Correspond to increases observed in that terrain type as compared to GCFE only

** Value of the response variable in GCFE terrain when year and elevation are kept constant

4.3.1.2 Survival and condition of grasses

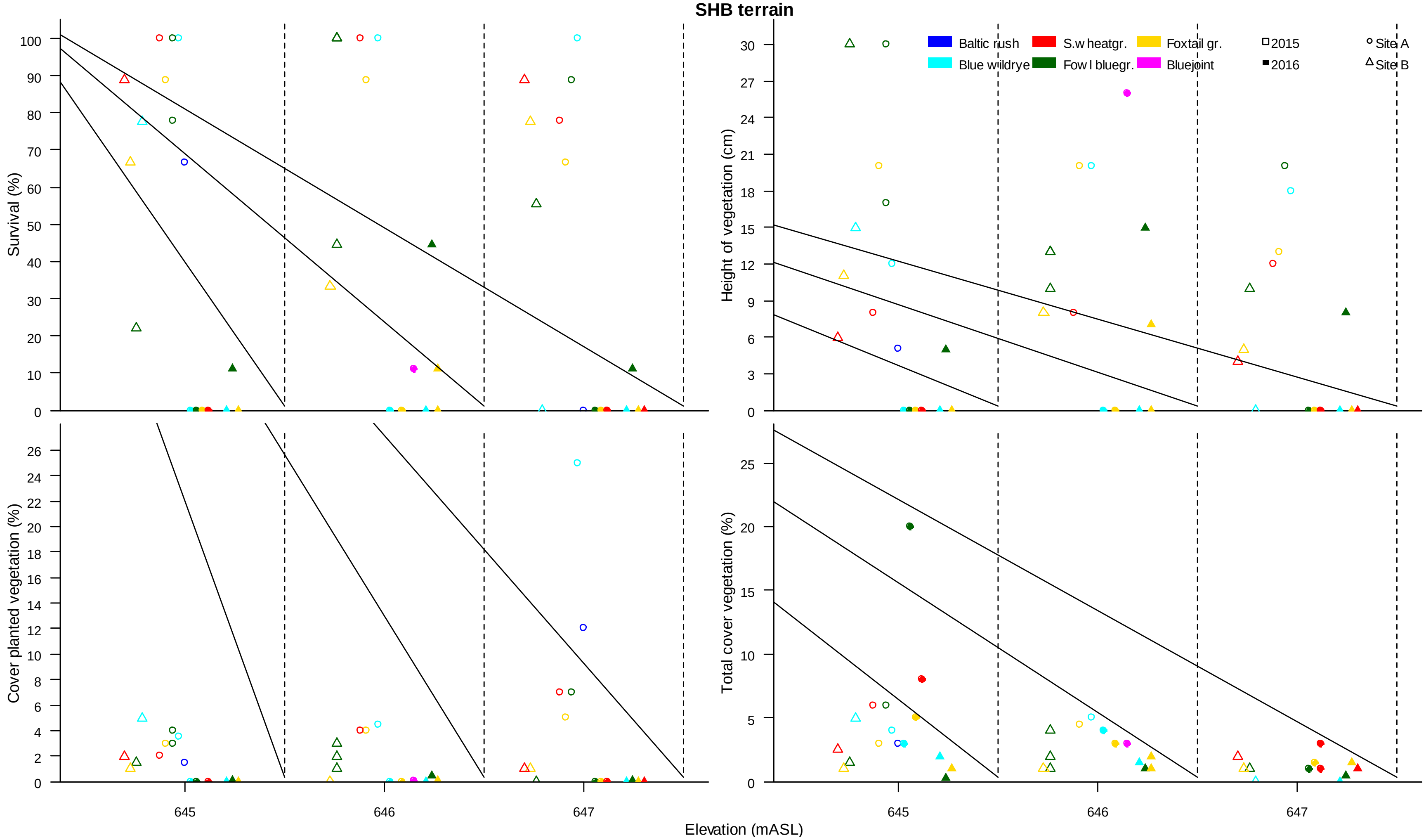


Figure 10. Variation in survival of grass (%), height of vegetation (avg, cm), cover of planted vegetation (%), and total cover of vegetation (%) in 2015 and 2016 per species and elevation in SHB terrain types (n=26 plots in 2 microsites). The vertical dashed lines are only to facilitate the split between elevation bands.

Very few of the grass plugs survived in SHB terrain in 2016; only Fowl bluegrass at Site B showed some survival in 2016, and one plot with Bluejoint and one with foxtail grass (Figure 10). Cover of planted vegetation and total cover were very low both in 2015 and 2016. Not surprisingly, GLMM models corroborate the sharp decline in survival with a significant decline in survival of 91%, in cover of planted vegetation of 99%, and in height of vegetation of 79% between 2015 and 2016, on average (Table 2). Elevation had only a significant negative impact on total cover of elevation (-54% per m). Survival, cover of planted vegetation or total vegetation did not vary much among species planted and Blue Wildrye (Baltic rush and Bluejoint not tested for lack of replicates; model fit and diagnostic plots not great overall, lots of 0s).

Table 2. Summary of GLMM regression models with partial (standardized) regression coefficients for each explanatory variable, along with their significance and effect size, in SHB terrain. The standard deviation for year was 0.504-0.5055 and 0.8393-0.8528 for elevation. Significance level α was assumed to be 0.1.

Response variable	Explanatory variable	regression coefficient	t	p-value	Effect size (per unit of X)
Survival	Year	-1.2	-12.15	0	-91%
	Elevation	-0.083	--	--	--
	Blue wildrye (intercept)	2.9	14.1	0	18.2%
	Fowl Bluegrass	0.54	--	--	--
	Foxtail Grass	0.23	--	--	--
	Slender Wheatgrass	0.35	--	--	--
cover planted	Year	-2.6	-10.2	0	-99%
	Elevation	-0.07	--	--	--
	Blue wildrye (intercept)	-1.65	-2.99	0.007	0.2%
	Fowl Bluegrass	0.2	--	--	--
	Foxtail Grass	-0.6	--	--	--
	Slender Wheatgrass	-0.3	--	--	--
total cover	Year	-0.11	--	--	--
	Elevation	-0.65	-2.4	0.025	-54%
	Blue wildrye (intercept)	0.13	--	--	--
	Fowl Bluegrass	0.26	--	--	--
	Foxtail Grass	0.33	--	--	--
	Slender Wheatgrass	0.97	--	--	--
height of vegetation	Year	-0.78	-9.1	0	-79%
	Elevation	-0.096	--	--	--
	Blue wildrye (intercept)	1.6	9.1	0	4.9%
	Fowl Bluegrass	0.7	2.96	0.009	2%*
	Foxtail Grass	0.196	--	--	--
	Slender Wheatgrass	-0.08	--	--	--

* the confidence interval of the regression coefficient crosses 0 on the coefficient plot

Survival of grass plugs was higher in STB terrain than in SHB terrain, though it remained generally quite low, especially at 646m where only bluejoint survived in 2016 (Figure 11). Foxtail grass, fowl bluegrass, and slender wheatgrass were the only other species that survived in one plot only in 2016. Again, cover of planted vegetation was very low both in 2015 and 2016 (< 4%) while total cover of vegetation was slightly higher, especially at 647m and 648m at Site B.

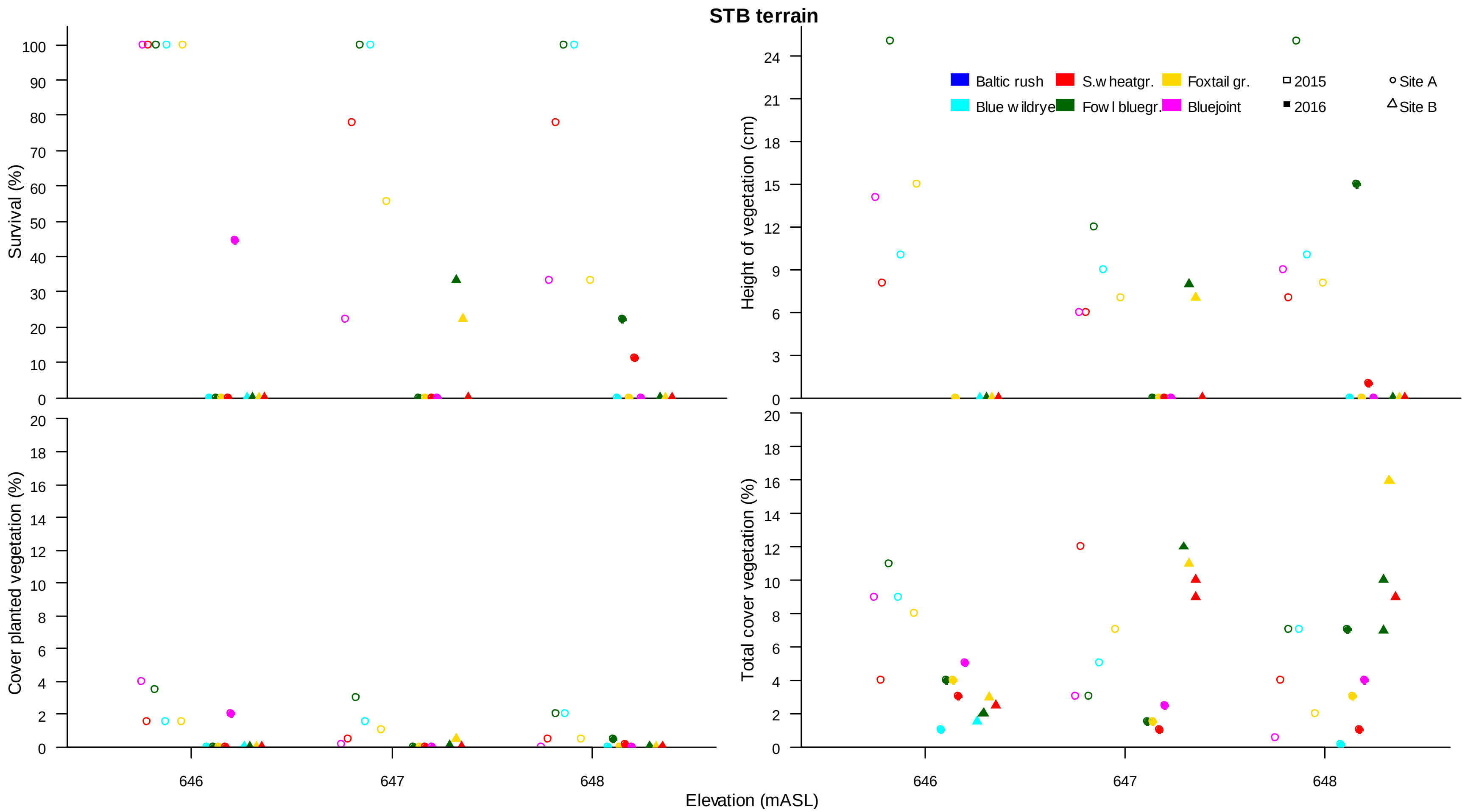


Figure 11. Variation in survival of grass (%), height of vegetation (ave, cm), cover of planted vegetation (%), and total cover of vegetation (%) in 2015 and 2016 per species and elevation in STB terrain types (n=15-27 plots in 2 microsites).

There were not enough replicates per combination of species planted, years and elevation in STB terrain to test formally.

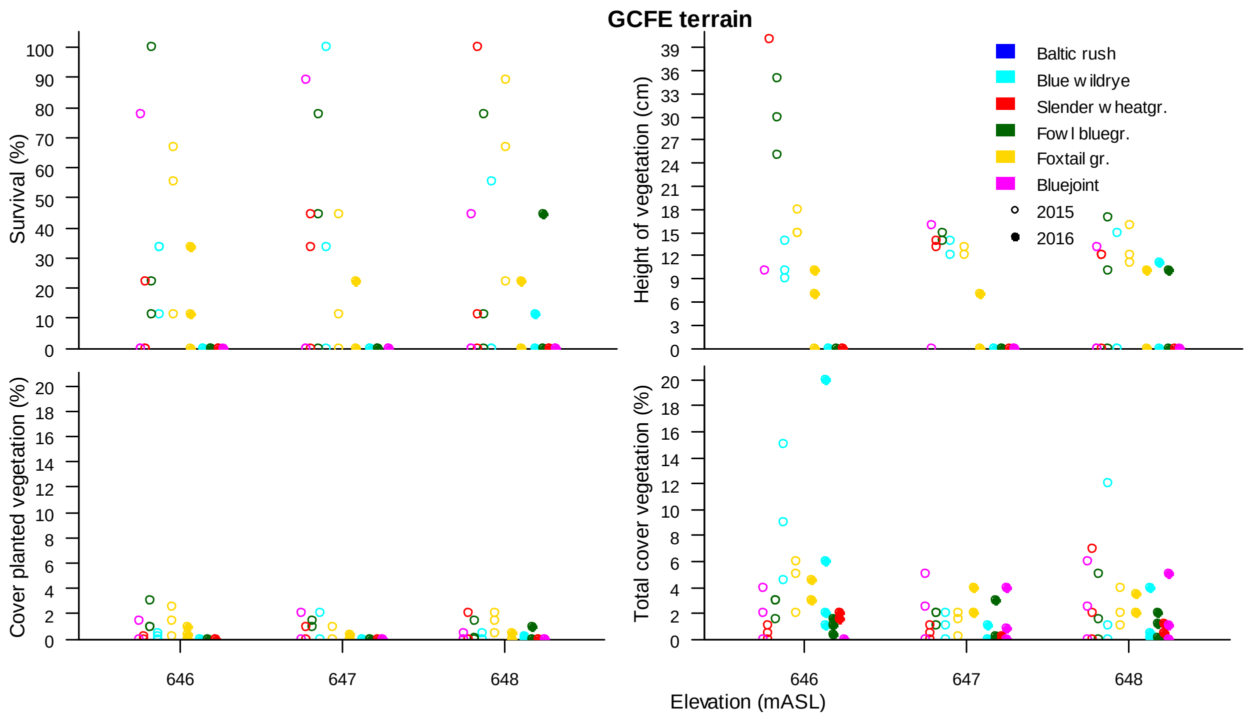


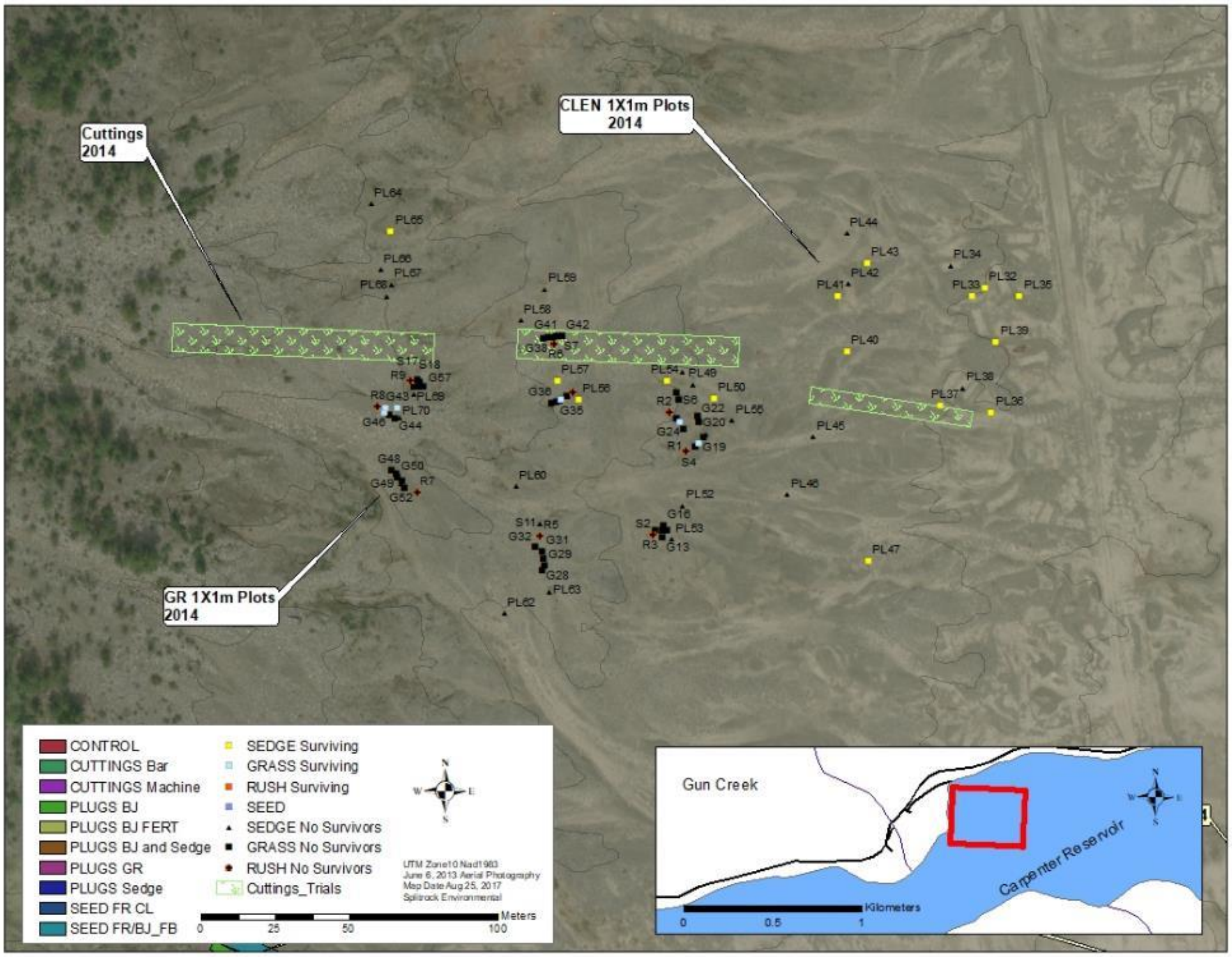
Figure 12. Variation in survival of grass (%), height of vegetation (avg, cm), cover of planted vegetation (%), and total cover of vegetation (%) in 2015 and 2016 per species and elevation in GCFE terrain types (n=45 plots in 9 microsites).

Survival of grass plugs also declined sharply in 2016 in GCFE terrain; once again, only foxtail grass survived at 646 m and 647 m, as well as fowl bluegrass and blue wildrye in one plot at 648m (Figure 12, Map 11). Height of vegetation and cover of planted vegetation also declined in 2016, while cover of total vegetation was more stable. Models show that survival significantly declined by 71%, cover of planted vegetation declined by 99%, and height of vegetation declined by 69% between 2015 and 2016, on average (Table 3). Elevation had only a significant negative impact on height of elevation (-17% per m). Survival, cover of planted vegetation or total vegetation did not vary much among species planted and Blue Wildrye (Baltic rush and Bluejoint not tested for lack of replicates; model fit and diagnostic plots not great overall, lots of zeros).

Table 3. Summary of GLMM regression models with partial (standardized) regression coefficients for each explanatory variable, along with their significance and effect size, in GCFE terrain. The standard deviation for year was 0.502-0.503 and 0.833-0.85 for elevation. Significance level α was assumed to be 0.1.

Response variable	Explanatory variable	regression coefficient	t	p-value	Effect size (per unit of X)
Survival	Year	-0.63	-7	0	-71%
	Elevation	0.03	--	--	--
	Blue wildrye (intercept)	2.4	10.2	0	11%
	Fowl Bluegrass	0.16	--	--	--
	Foxtail Grass	0.54	--	--	--
	Slender Wheatgrass	-0.2	--	--	--
cover planted	Year	-2.1	-7.2	0	-99%
	Elevation	-0.21	--	--	--
	Blue wildrye (intercept)	-5.4	-8	0	0.0%
	Fowl Bluegrass	1.5	--	--	--
	Foxtail Grass	2.7	2.73	0.01	15%*
	Slender Wheatgrass	-0.2	--	--	--
total cover	--	--	--	--	--
height of vegetation	Year	-0.58	-7.7	0	-69%
	Elevation	-0.16	-1.9	0.065	-17%
	Blue wildrye (intercept)	1.95	12.2	0	7.0%
	Fowl Bluegrass	0.4	--	--	--
	Foxtail Grass	0.45	2	0.052	1.6%
	Slender Wheatgrass	0.1	--	--	--

* the confidence interval of the regression coefficient crosses 0 on the coefficient plot



Map 11. Location of trial plots from 2014 in GCFE terrain, with plants surviving through to 2016.

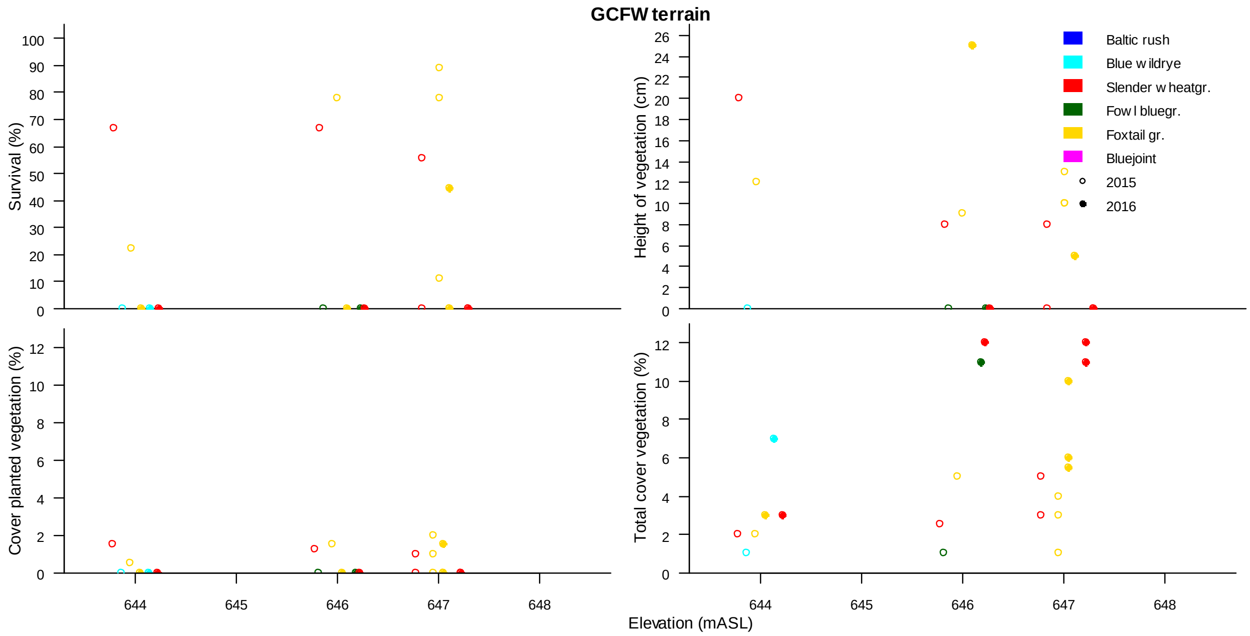


Figure 13. Variation in survival of grass (%), height of vegetation (ave, cm), cover of planted vegetation (%), and total cover of vegetation (%) in 2015 and 2016 per species and elevation in GCFW terrain types (n=11 plots in 1 microsite).

Only one plot with foxtail grass survived to 2016 in GCFW terrain (Figure 13). Cover of planted vegetation was low in both years (<2%), but overall cover was higher, especially in 2016 at 646 and 647m (up to 12%). There were not enough replicates per combination of species planted, years and elevation in GCFW terrain to test formally.

4.3.1.3 Survival and condition of rushes

Hardly any planted rush survived in 2016, and what did (in only two plots a single plug survived, one in the SHB and one in the GCFE terrains) was with very limited survival (<15%, Figure 14).

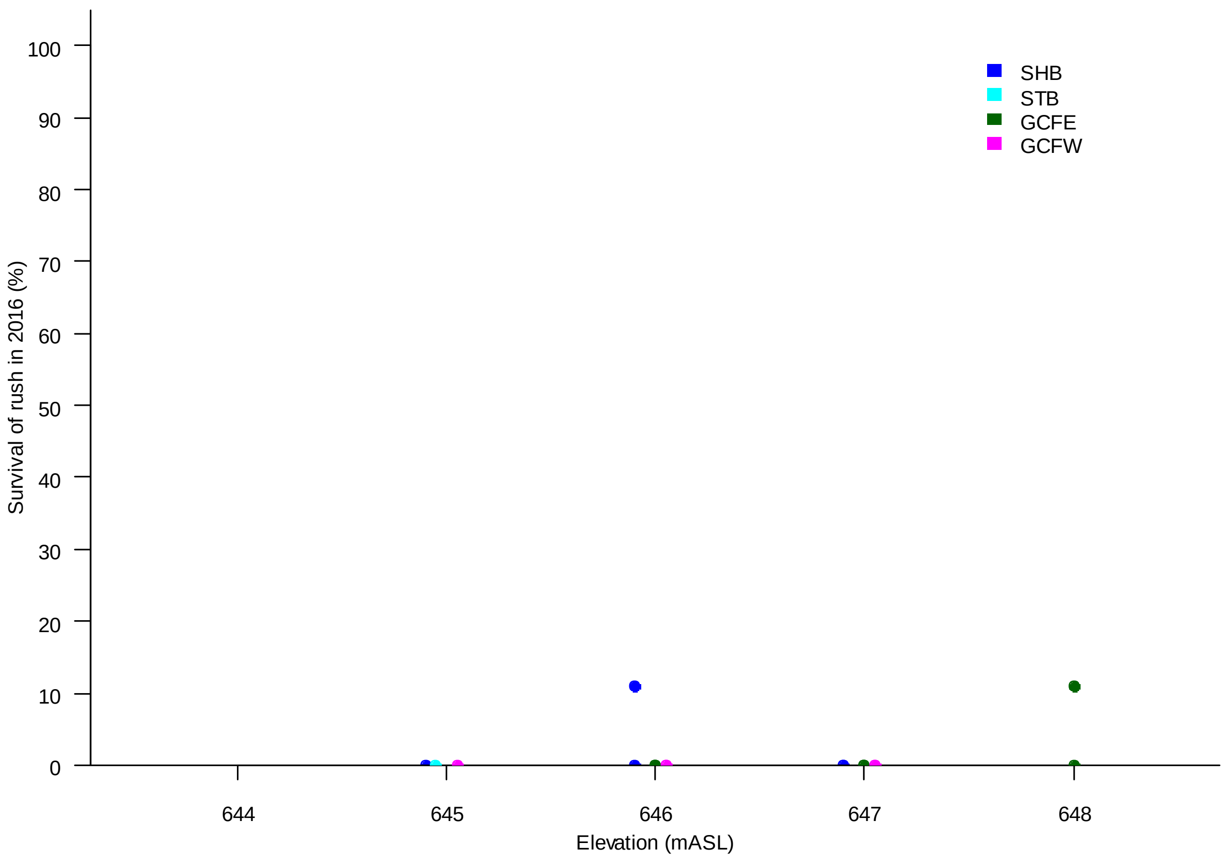


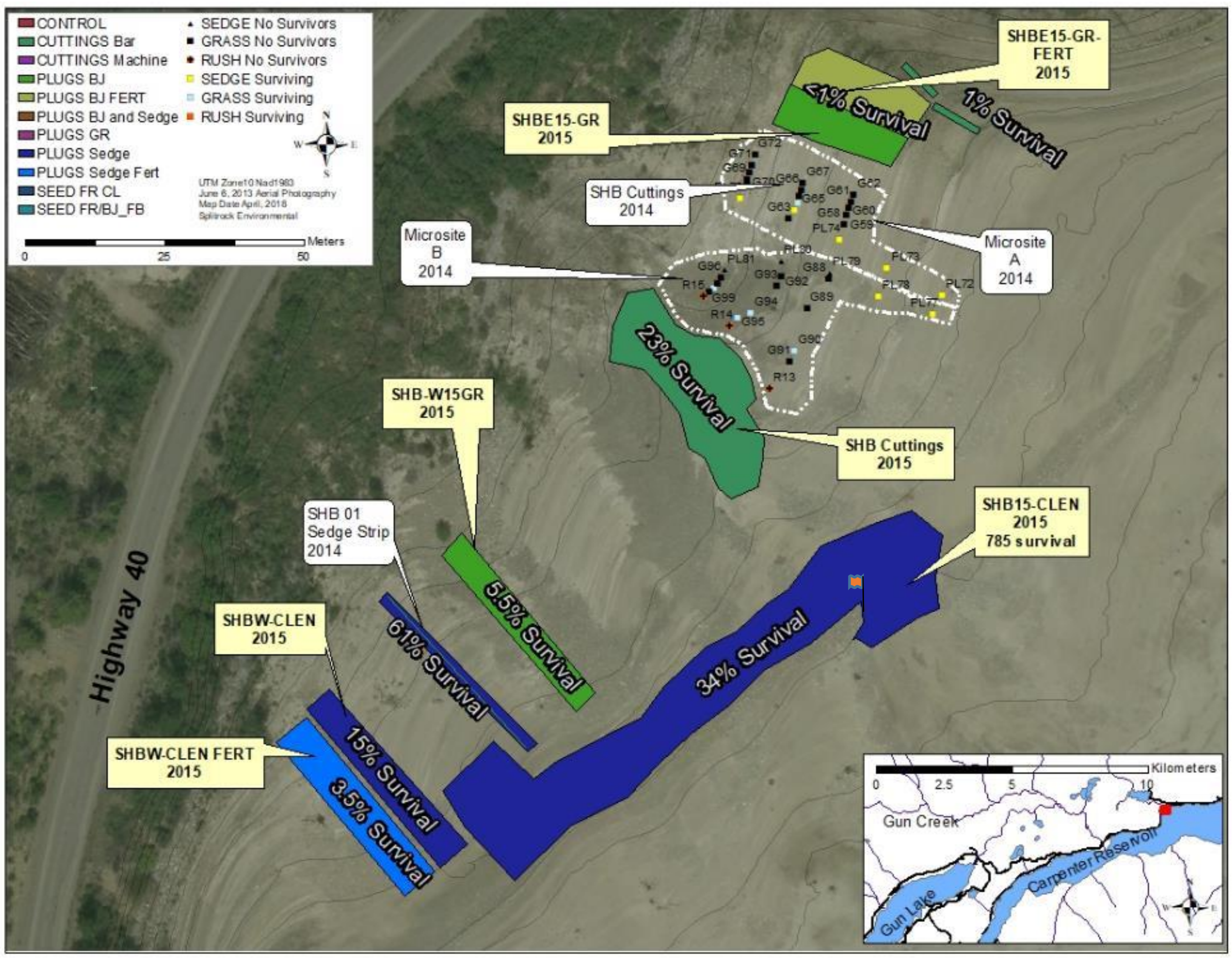
Figure 14. Survival in 2016 (%) of rush planted in 2014 per terrain type and elevation.

4.3.2 Results of monitoring of the 2015 trial plots

Shallow Beach (SHB) terrain

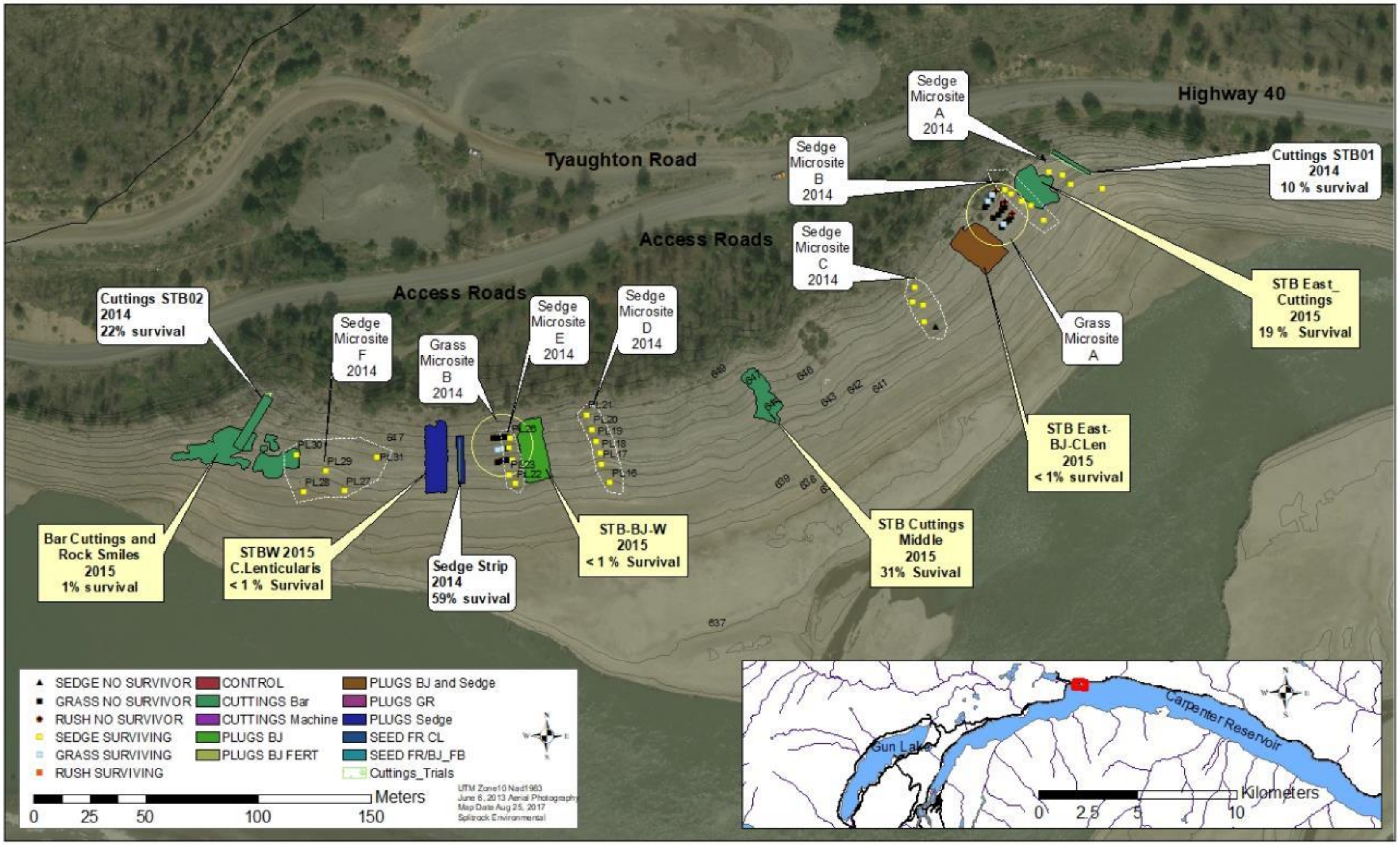
Three polygons were planted with *C.lenticularis* plugs in 2015 and monitoring results are shown in Map 12. The best survival from the 2015 planting was in the polygon at the lowest elevation (SHB15-CLEN), while the lowest survival was recorded at the polygon where fertilizer tea bags were planted along side each plug.The most successful polygon (SHB15-CLEN) had one third survival of planted sedge plugs. Planting at this polygon was targeted into a sandy, narrow bench between 642 and 643 m ASL elevation. Plants were in fair to good vigour, but the areas at higher elevations in the west end, where the substrate was coarser, had lower survival. A polygon of C. lenticularis was also planted with fertilizer (SHBW-CLEN FERT 2015), and had very low survival. Interestingly in this polygon, plants were planted with tea bag fertilizers and although sedge plugs did poorly, the effect of the fertilizer was evident in the natural plants growing at the site (Figure 15). Two annual native species were observed to be predominantly responding to the planted fertilizer, small flowered evening star (*Mentzelia ablicaulis*) and Scouler's popcorn flower (*Plagiobothrys scouleri).* Only one plug was observed in excellent vigour in the fertilized polygon. Survival of plugs planted in the adjacent non-fertilized polygon (SHBW CLEN) was higher but only a quarter of that experienced in the 2014 linear strip trial.

Polygon SHBE 15-GR FERT was planted with bluejoint reedgrass and one half was treated with a tea bag of fertilizer. Nineteen plots were used to sample the polygon; nothing had survived because of faunal excavations throughout the area. A couple of live plugs were observed out of 1000 planted.



Map 12. Location of the treatments in SHB terrain done over three polygons in 2015, with the results of monitoring conducted in 2016.

Figure 15. Evident growth response of natural vegetation in 2016 due to fertilizer bags planted along C. lenticularis plugs at the SHB terrain.



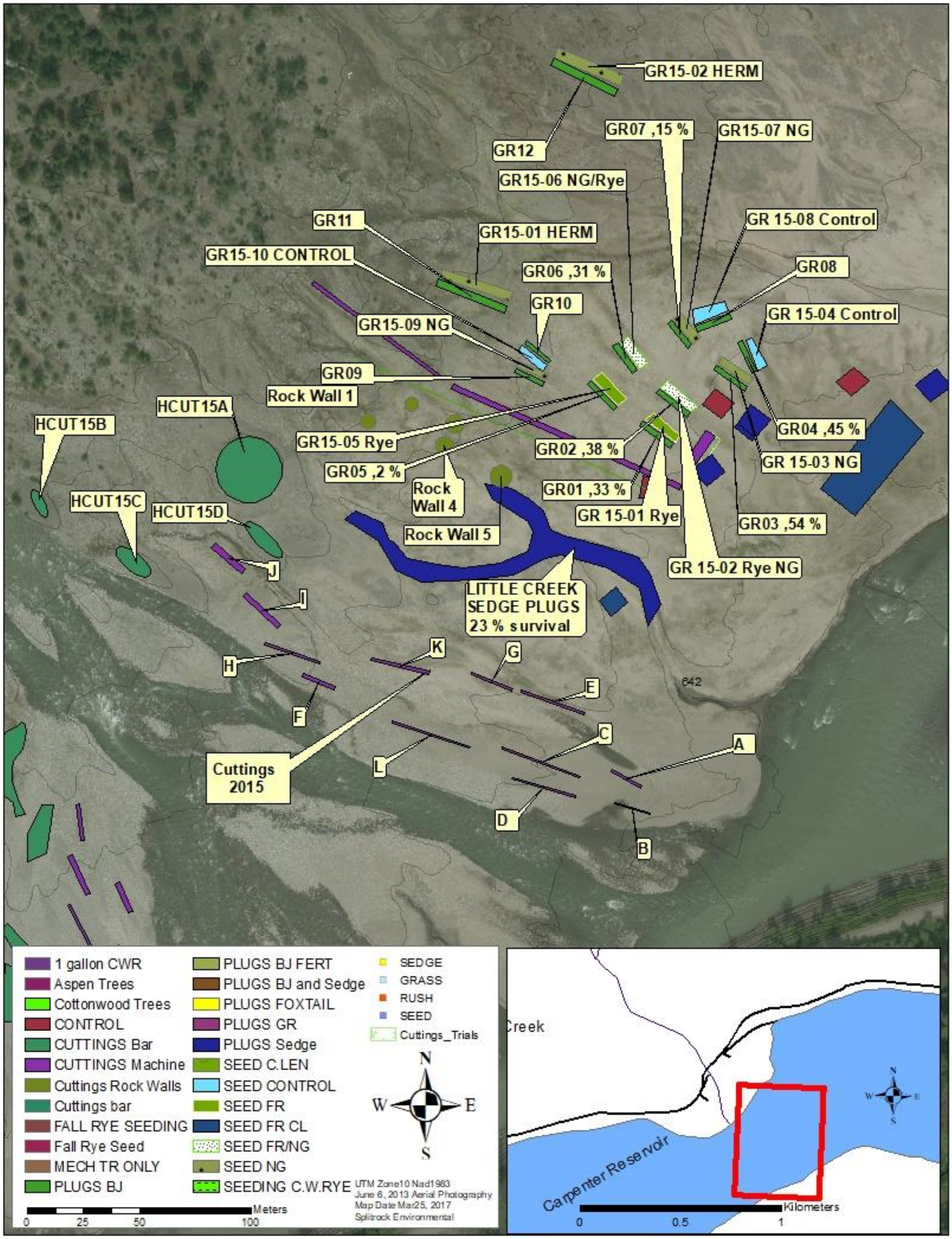
Map 13. Location of the treatments in STB terrain done over three polygons in 2015, with the results of monitoring conducted in 2016.

STB terrain

Two additional C. lenticularis polygons were planted in 2015 in STB terrain (STBW 2015 CLEN and STB East BJ-CLEN2015, Map 13). Plant survival in 2016 was very poor in both polygons, and survival was limited to only a few live plants growing in both polygons.

GCFE terrain

A polygon named ‘Little Creek’ was planted with 1514 C. lenticularis plugs in 2015, and 23 % of planted plugs survived through 2016. Seven of the twelve polygons (GR01-12) planted with Bluejoint reedgrass plugs in GCFE terrain in 2015 showed a range of survival between 2 and 66 per cent (Map 14). The highest survival was in a site at an elevation of 644 m ASL in a flat, silt-sand, slightly concave substrate (Figure 16). Plants there were observed to be of fair vigor. Adjacent plots seeded with a variety of seed mixes that included fall rye, fall rye and native grass mix, and native grass mix only (bluejoint reedgrass and fowl bluegrass) were monitored in 2016. Grass seedlings were very small but it appears there was some colonization taking place in polygons seeded with bluejoint and fowl bluegrass seed mix. There was no evidence of carry over fall rye plants.

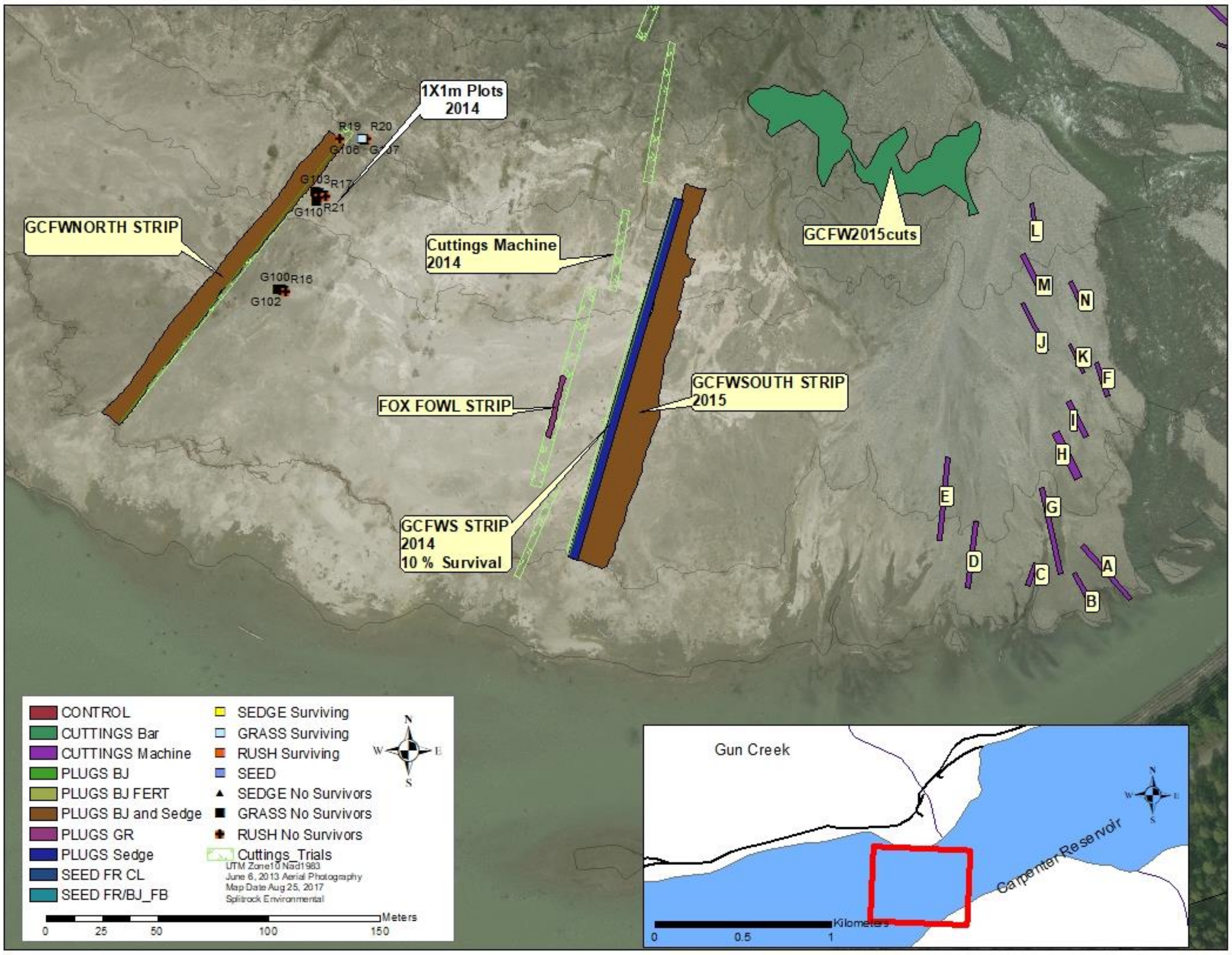


Map 14. Location of treatments performed in 2015 around the Gun Creek Fan East (GCFE) terrain. The labels indicate a selection of survival success in planted polygon.

Figure 16. Image of the most successful polygon (GR03) in terms of plant survival in 2016 (644 m ASL).

GCFW terrain

Two large polygons were planted with C. lenticularis and bluejoint reedgrass in GCFW terrain in 2015 (Map 15). Given time constraints, these polygons were sub-sampled in 2016 using 1X1m plots randomly thrown. Bluejoint reedgrass was recorded to survive in fair to good condition in three of the 15 subplots sampled in the GCFW15-N polygon and in seven of 16 polygons in the GCFW-S polygon. It is estimated from sub-sample plots that survival rates for plugs planted in the GCFW-N polygon were 26% and 54% in GCFW-S polygon. Bluejoint reedgrass was the predominant species planted and surviving in plots, and no plugs of C.lenticularis were detected in the random sampling of the GCFW terrain.



Map 15. Location of treatments performed in 2015 around the Gun Creek Fan West (GCFW) terrain. Where available, survival success in planted polygon is indicated.

4.3.2.1 Paired control and treated polygons

Planting of CLEN in LMF terrain

Random sub-plots were sampled to assess survival and conditions of *C. lenticularis* (CLEN) planted in 2015 in LMF polygons. In addition, total tallies of live plugs were assessed for each polygon. Based on the 1X1 m plots, it appeared that almost all the plugs of CLEN that were planted in 2015 in LMF terrain (2788 total) survived in 2016 (Figure 17), except for five plots where no plants were observed. Total cover of vegetation was fairly similar between control and treated plots, except for plot CLEN02 (641 m) where treated plots had slightly higher total vegetation cover, and plot CLEN09 (644 m), where control plots had a higher cover in vegetation (Figure 18). Based on tallies of entire polygons, a fair amount of variation in survival occurred with between 25% and 100% survival in treated polygons (Map 16).

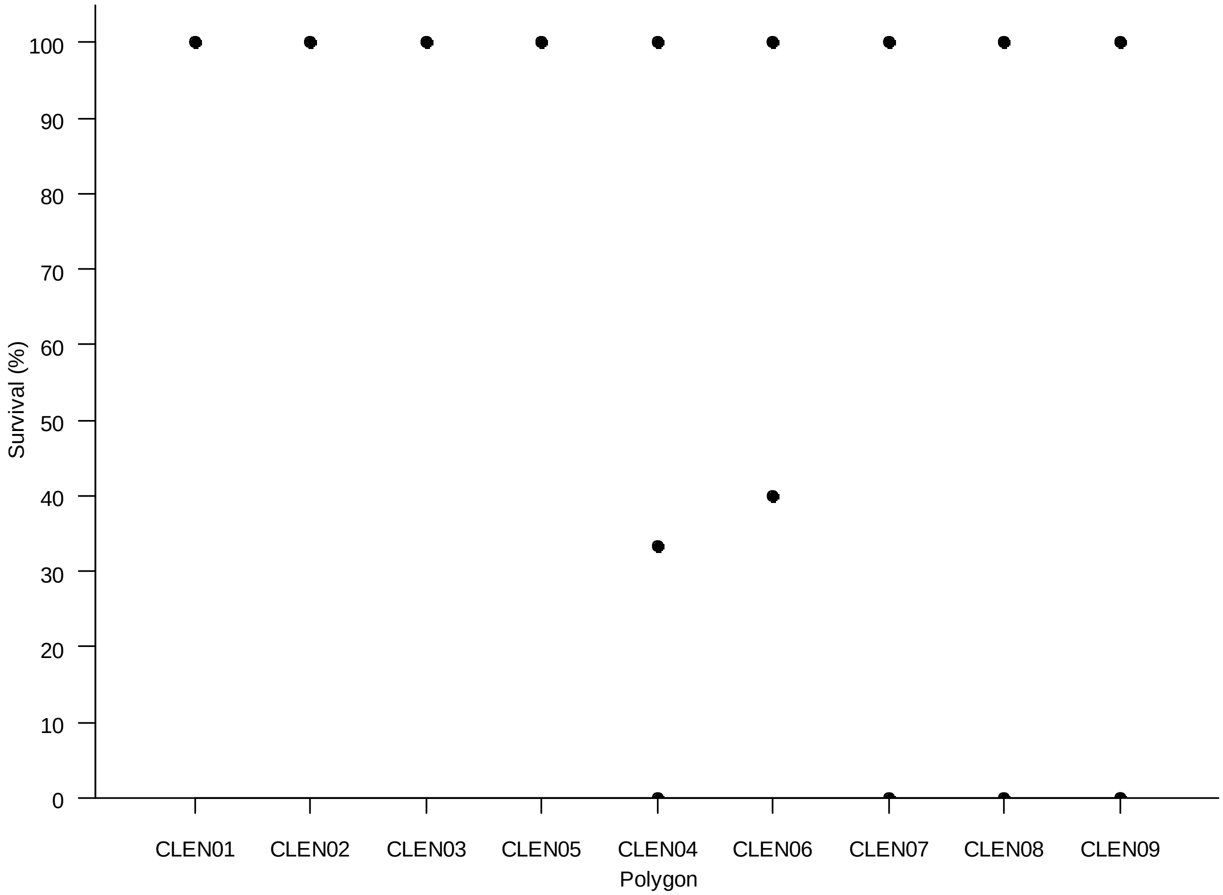


Figure 17. Variation in survival (%) of CLEN plugs planted in 2015 at nine polygons. Polygons are ordered from low (641m, CLEN01 to CLEN05), to mid elevations (CLEN04 and 06 at 642m, CLEN07 at 643m, CLEN08 at 643.5m, and CLEN09 at 644m).

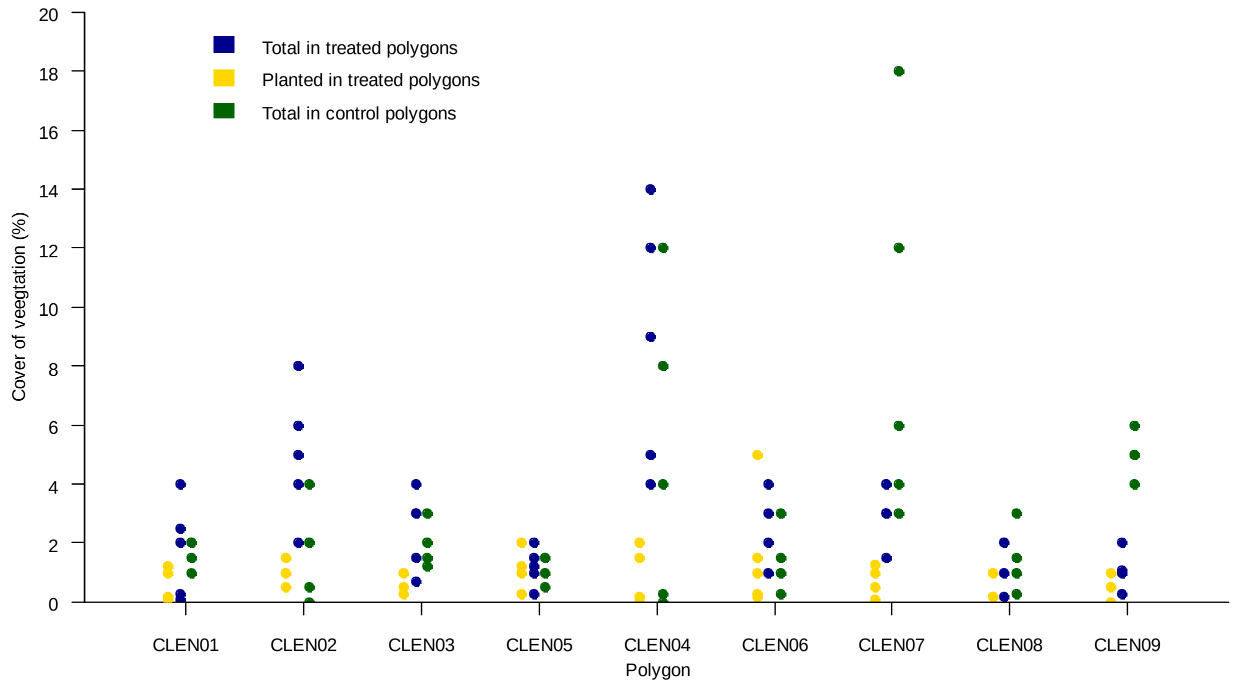
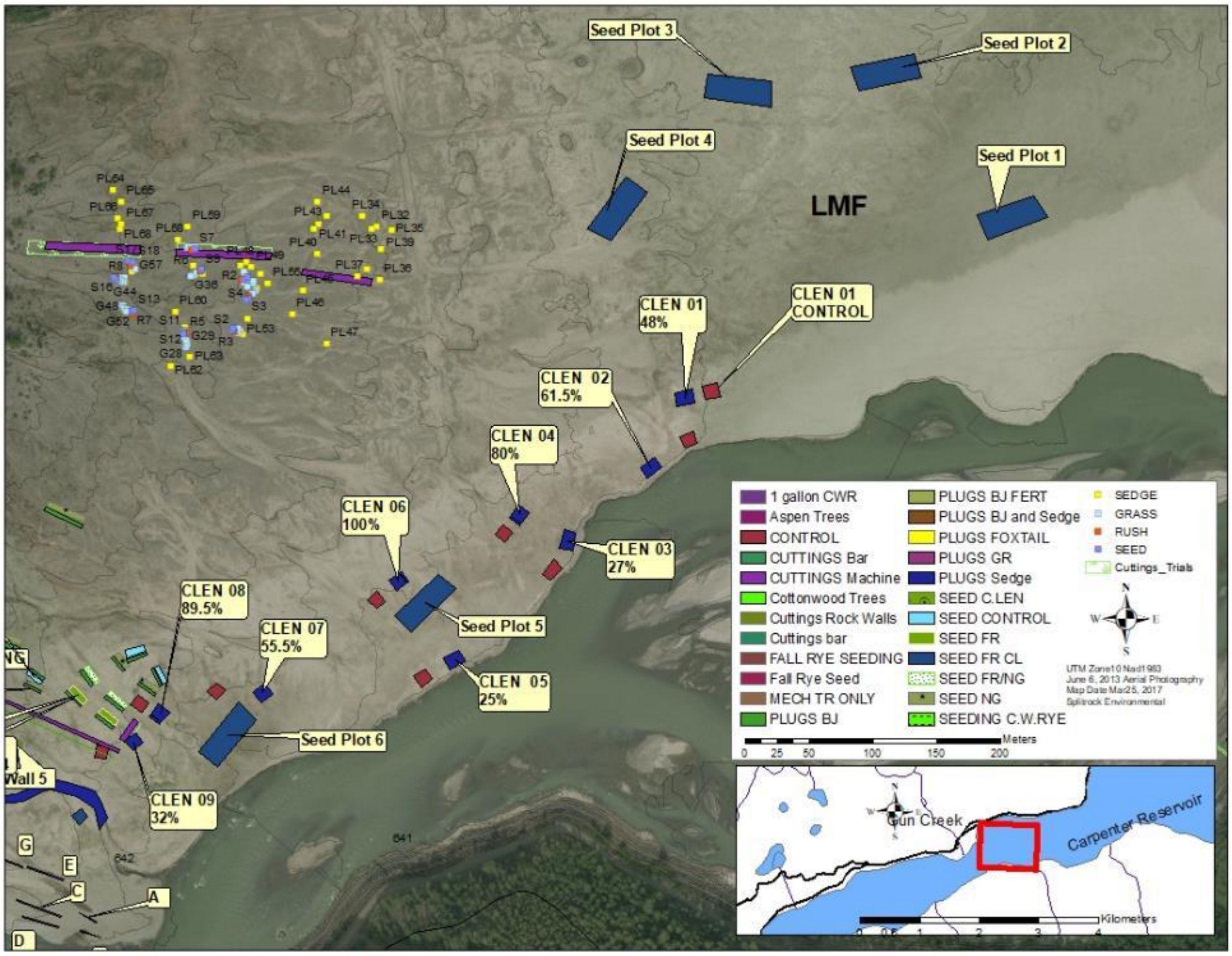


Figure 18. Variation in total cover of vegetation (%) of CLEN plugs planted in 2015 in control and treated polygons, as well as cover of planted plugs in the treated polygons (in yellow). Polygons are ordered from low (641m, CLEN01 to CLEN05), to mid elevations (CLEN04 and 06 at 642 m, CLEN07 at 643 m, CLEN08 at 643.5 m, and CLEN09 at 644 m).

Average total vegetation cover in treated and control polygons was low (<10%) with only two plots exceeding 5% (Figure 18). The highest cover was observed in the treated polygon CLEN04 and control polygon CLEN07. CLEN 09 was the only polygon pair where there was a clear difference in total cover between control and treated plot (Figure 18), though the average difference in cover was only 4%. Planted *C. lenticularis* corresponded to an average of 42% of total vegetation cover, and ranged between 10% and 90% (Figure 18,)



Map 16. Location of the polygons treated with C.lenticularis and seed trials in the Low Mud Flat (LMF) terrain. The overall survival in 2016 of CLEN plugs is indicated.

4.3.2.2 Seedlings density

Polygon Seed 1 (Plot 1) clearly had a higher density of seedlings in 2016, while the other five plots looked similar with very low survival (<10%, Figure 19). There were no significant differences in seedlings density between the treatments and the control but the model fit was not great, and results are not reported.

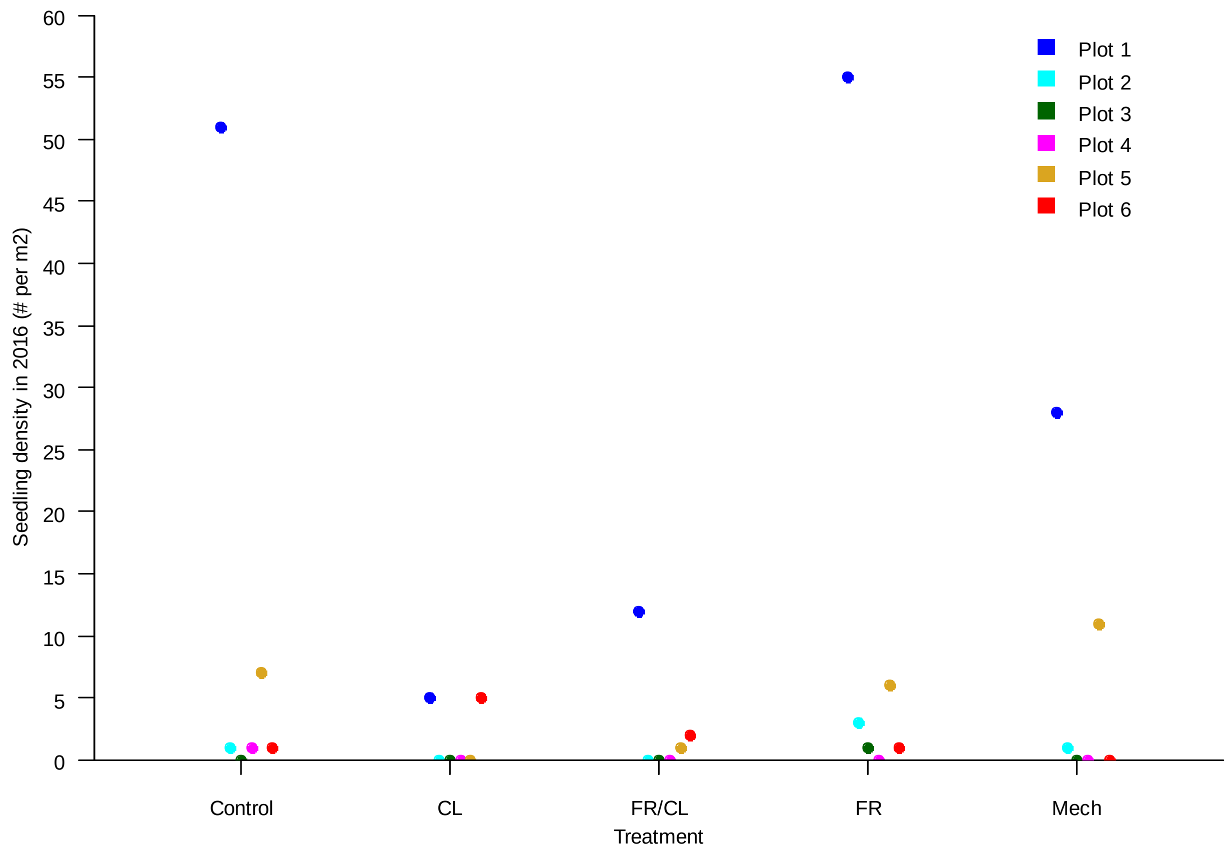


Figure 19. Variation in seedling density of C. lenticularis (# per m^2) per treatment in 2016.

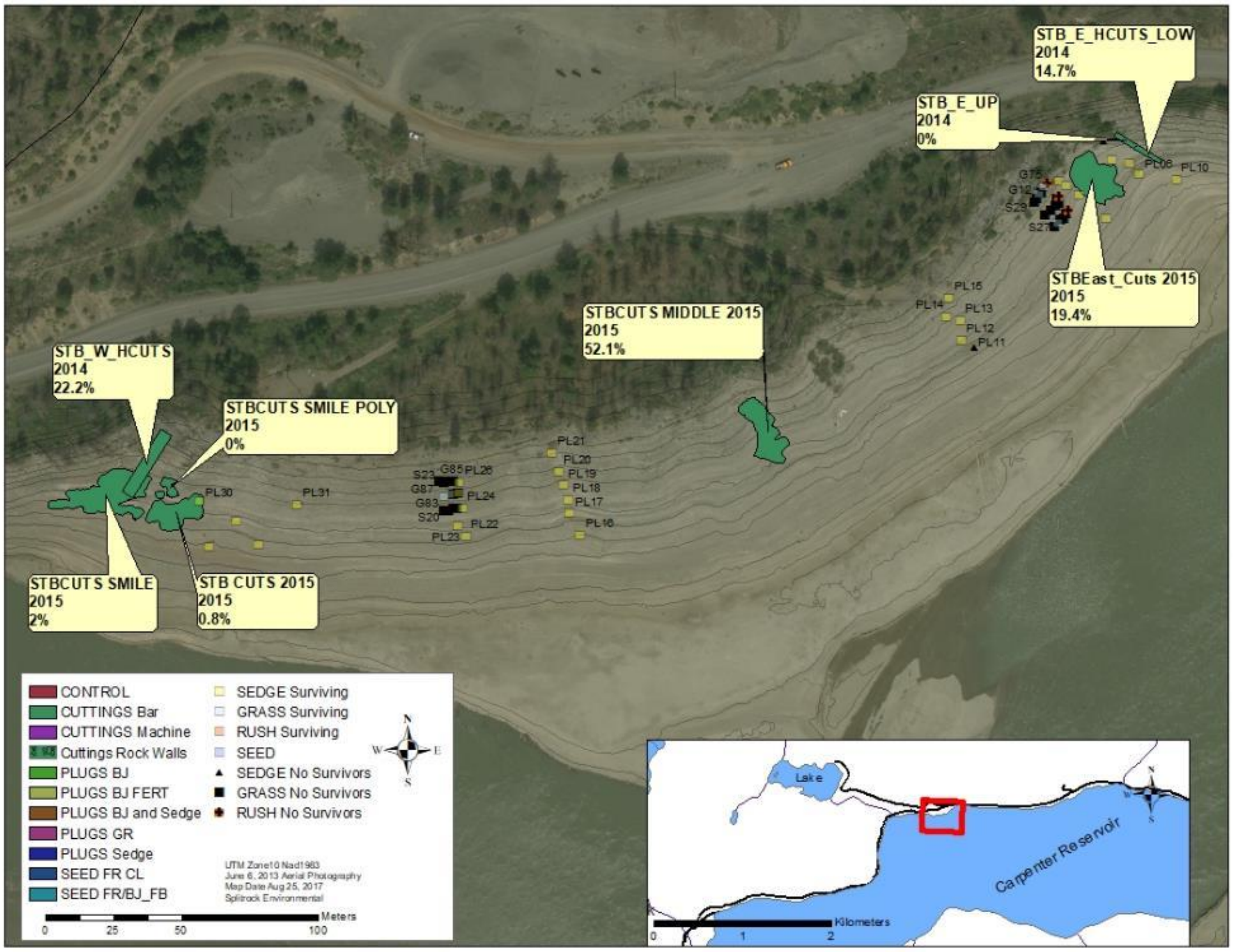
4.3.2.3 Monitoring of live-stake cuttings in 2016

Monitoring of live-stake cuttings was carried out by tallying live stems in June 2016 at all sites where cuttings had been planted from 2014 through to 2016 (**Error! Reference source not found.**). All the sites where cuttings were machine-planted in 2016 were monitored on the Gun Creek Fan West (GCFW) and at elevations of 646-650 m ASL in the upper drawdown zone. Most of the 2016 live-stakes were doing well several months after planting, although these stakes would most likely not have fully rooted and established yet.

The planting of live-stake cuttings in 2015 was widespread with sites in five of the main terrain types (STB, SHB, SAF, GCFE, and GCFW). Machine-planted sites were carried out on both the east and west sides of Gun Creek in 2015. Many of these planting sites experienced significant damage over the winter of 2015-2016 from flooding and floating debris that girdled many of the larger standing cuttings. Following the girdling, ice damage occurred across many of the 2015 cuttings sites. When the frozen layer of ice on the surface of the reservoir dropped with sinking water levels, the weight of the ice applied a crushing mechanical force on many of the 2015 cuttings (Figure 20).

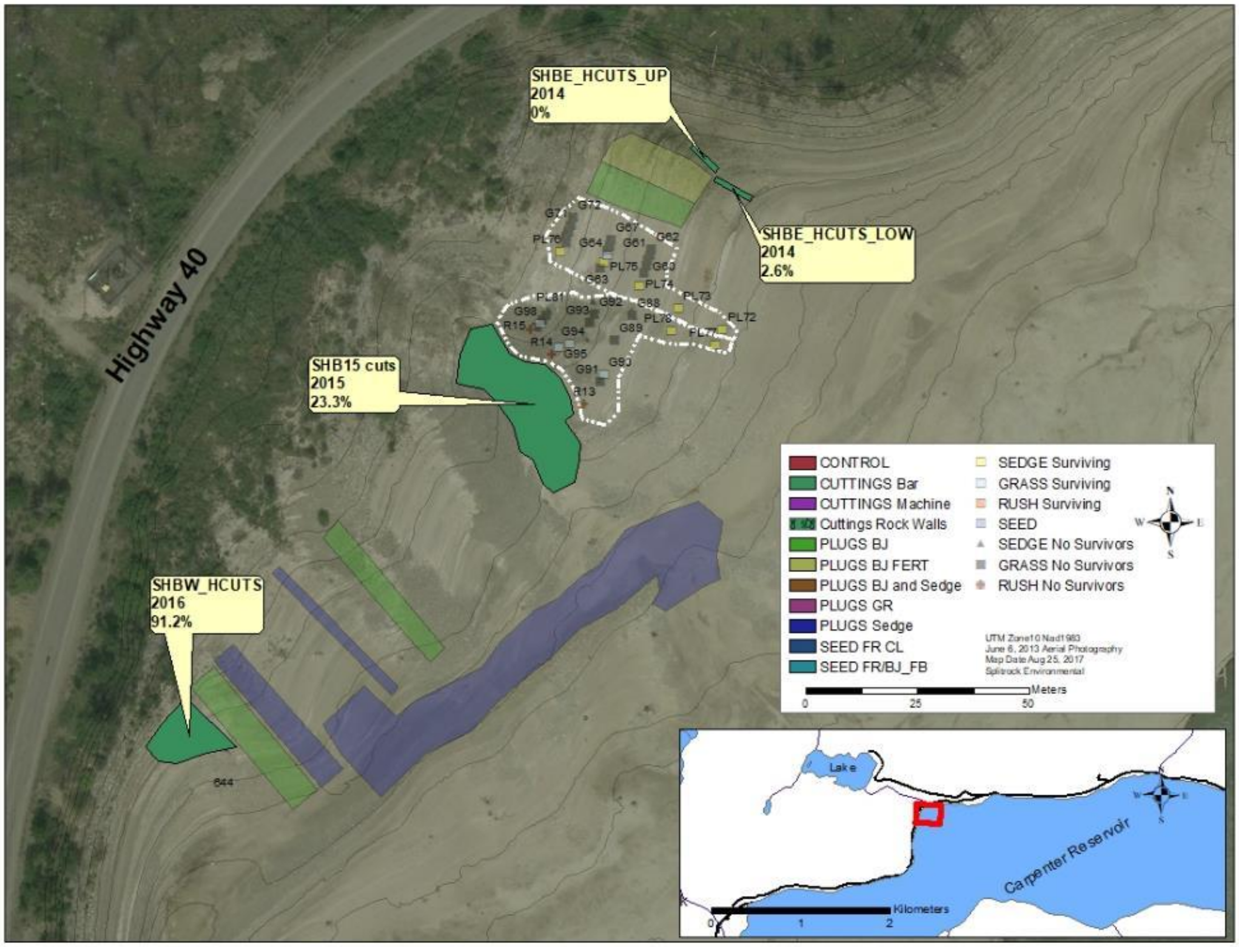
Figure 20. Example of the mechanical damage from ice on live-stake cuttings planted in 2015 (STB terrain).

At the STB terrain, two sites planted with cutting in 2014 (one at the east and one at the west end) were monitored in 2016 (STB East and West HCUTS 2014, Map 17). The 2014 west end site had plants surviving throughout the length of the polygon. In the east site, cuttings were established at low to mid elevations. Three polygons had been hand-planted with live-stake cuttings in 2015 at the STB site, and the center polygon had the highest percentage of successful establishment (> 50%, Map 17). About 5% of live-stakes suffered mechanical damage from ice and an additional 20% were cut by beaver (*Castor canadensis*) at this center polygon. The west end site had the lowest survival with only 2 % of planted live-stakes cutting surviving, while at the east end polygon, there was close to 20% survival (and 43% of cuttings cut by beaver). Of note, a fair number of stems cut by beaver, and some of the willow stems crushed by ice, were still alive and re-sprouting from the base of the cuttings.



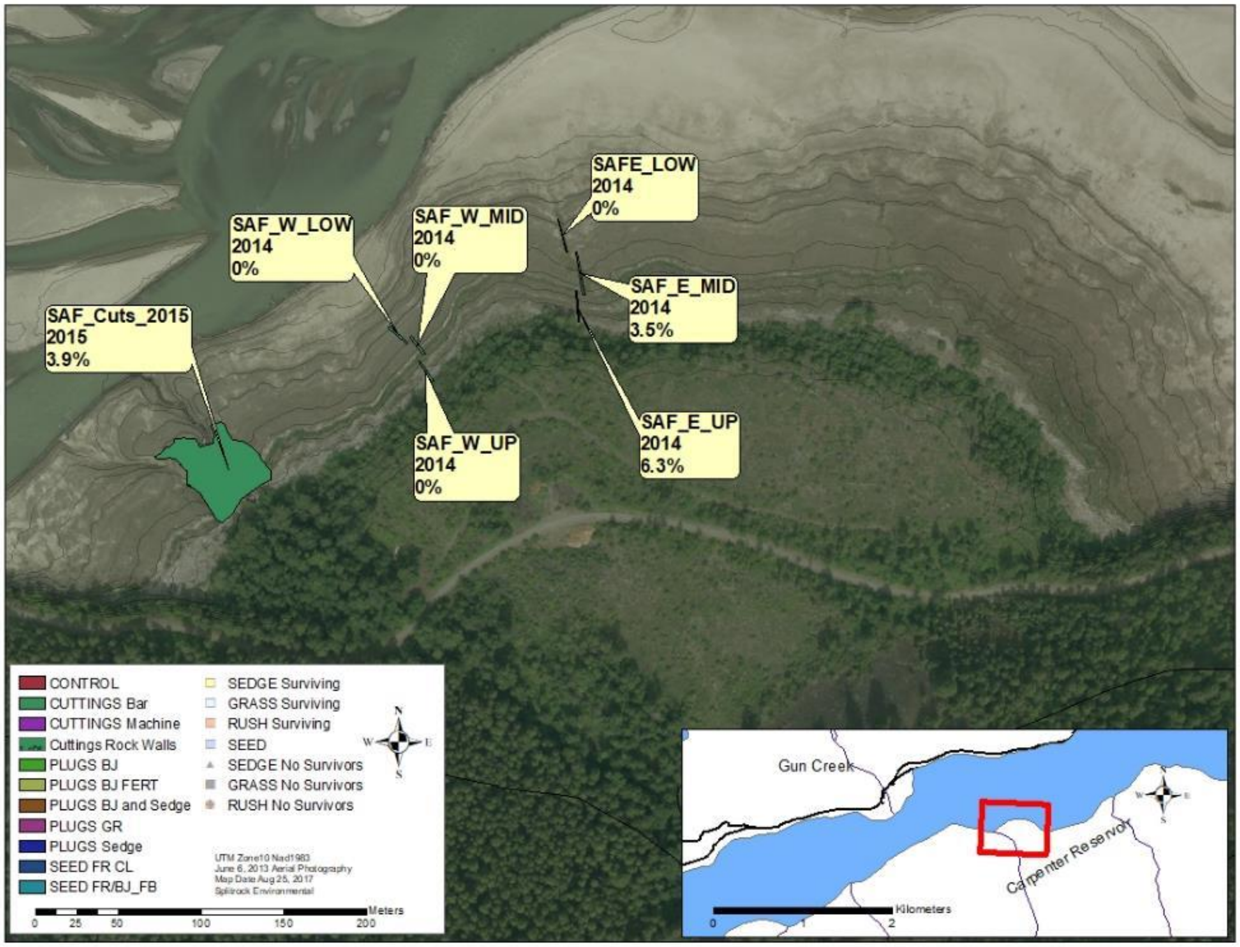
Map 17. Location of live-stake cuttings planted in STB terrain in 2014 and 2015, with survival (%) observed during monitoring performed in 2016.

The live-stake cuttings planted in 2014 in SHB terrain had relatively little survival with only a single cutting established after three growing seasons (Map 18). In 2015 an additional patch of live-stake cuttings was planted in the center of the SHB site (Map 18). Nearly a quarter of these live-stake cuttings established and grew by the second growing season in 2016. However, thirty-eight per cent of the stems were cut by beaver, and the harvesting was carried out by beavers when the water levels in the reservoir were near full pool judging by the height of the cuts. An early survey of the patch of live-stake cuttings planted in 2016 at the west end of the SHB indicated 8 percent of cuttings did not make it through the initial installation phase.



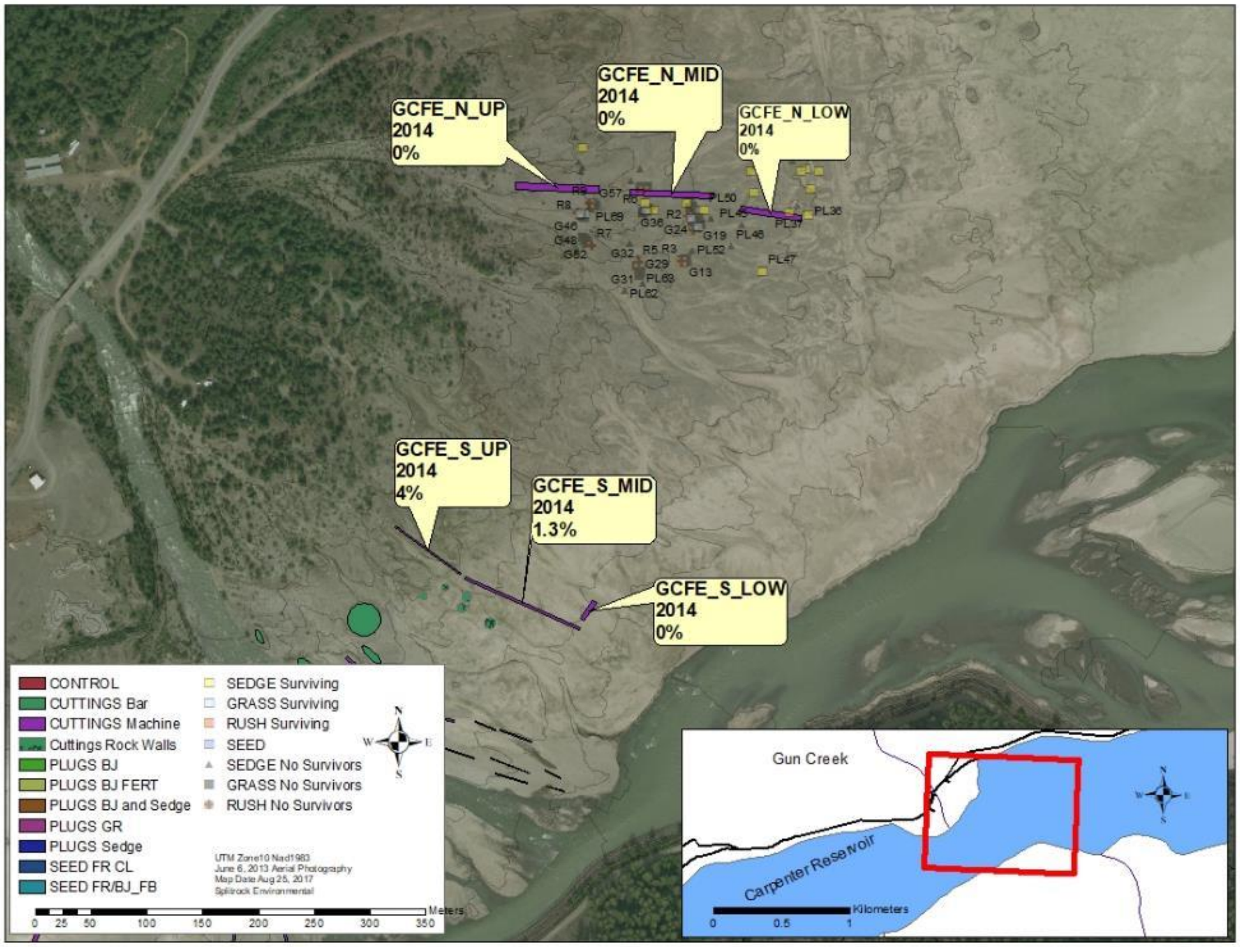
Map 18. Location of live-stake cuttings planted in SHB terrain in 2014 and 2015, with survival (%) observed during monitoring performed in 2016.

Live-stake cuttings planted in 2014 and 2015 were also monitored in 2016 at the steep alluvial fan (SAF) on the South side of Carpenter Reservoir (Map 19). The survival of live-stake cuttings planted in 2014 was limited to several plants established in both the mid and upper eastern polygons (Map 19). In 2015 live-stake cuttings were planted in a larger area around a small creek flowing through the alluvial fan on the South side of Carpenter Reservoir. Survival at this site was fairly low with just under 4% of stems established in 2016.

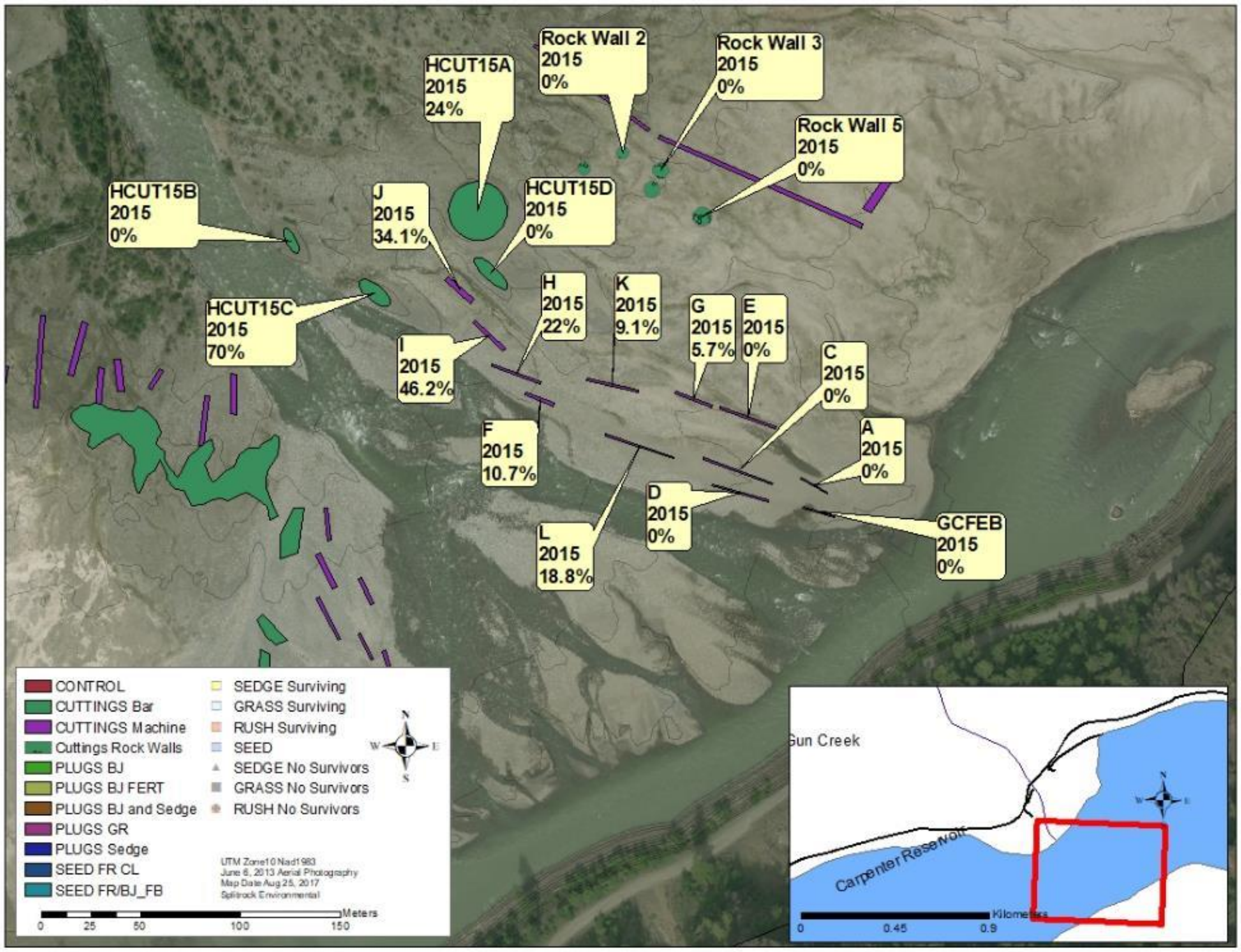


Map 19. Location of live-stake cuttings planted in SAF terrain in 2014 and 2015, with survival (%) observed during monitoring performed in 2016.

The live-stake cuttings planted in 2014 at the Gun Creek Fan East (GCFE) terrain had limited establishment into the third growing season (Map 20). No cuttings established within the north polygons, while some limited establishment was observed in the south polygons. As mentioned earlier, several live-stake cuttings east of the fan suffered ice damage. Polygons at low elevation showed no survival (A, B, C, D, E, Map 21), while all machine-planted polygons at mid-elevation (F, G, H, I, J, K, L, Map 18) had some level of establishment success in 2016 (between 5% and 45%). Two of the four hand-planted polygons located close to Gun Creek experienced successful establishment but the other two polygons had no survival. All five of the 'rock wall' polygons that were also hand-planted in 2015 experienced no establishment success either (Map 21). These sites had hand-built low rock walls constructed prior to the planting of the live-stake cuttings to create beneficial microsites that would encourage sediment deposition when flooded (Scholz, 2015).



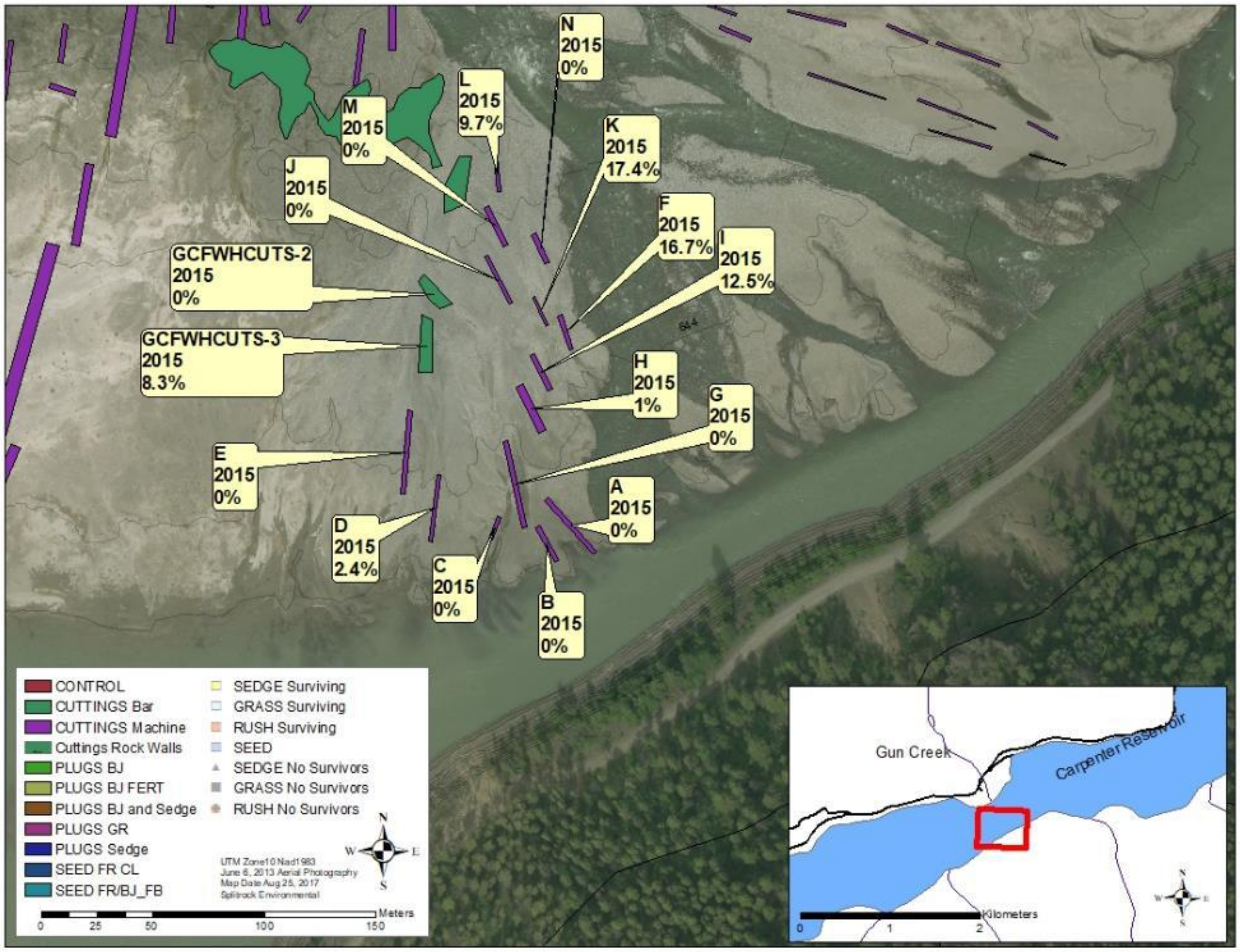
Map 20. Location of live-stake cuttings planted in GCFE terrain in 2014, with survival (%) observed during monitoring performed in 2016.



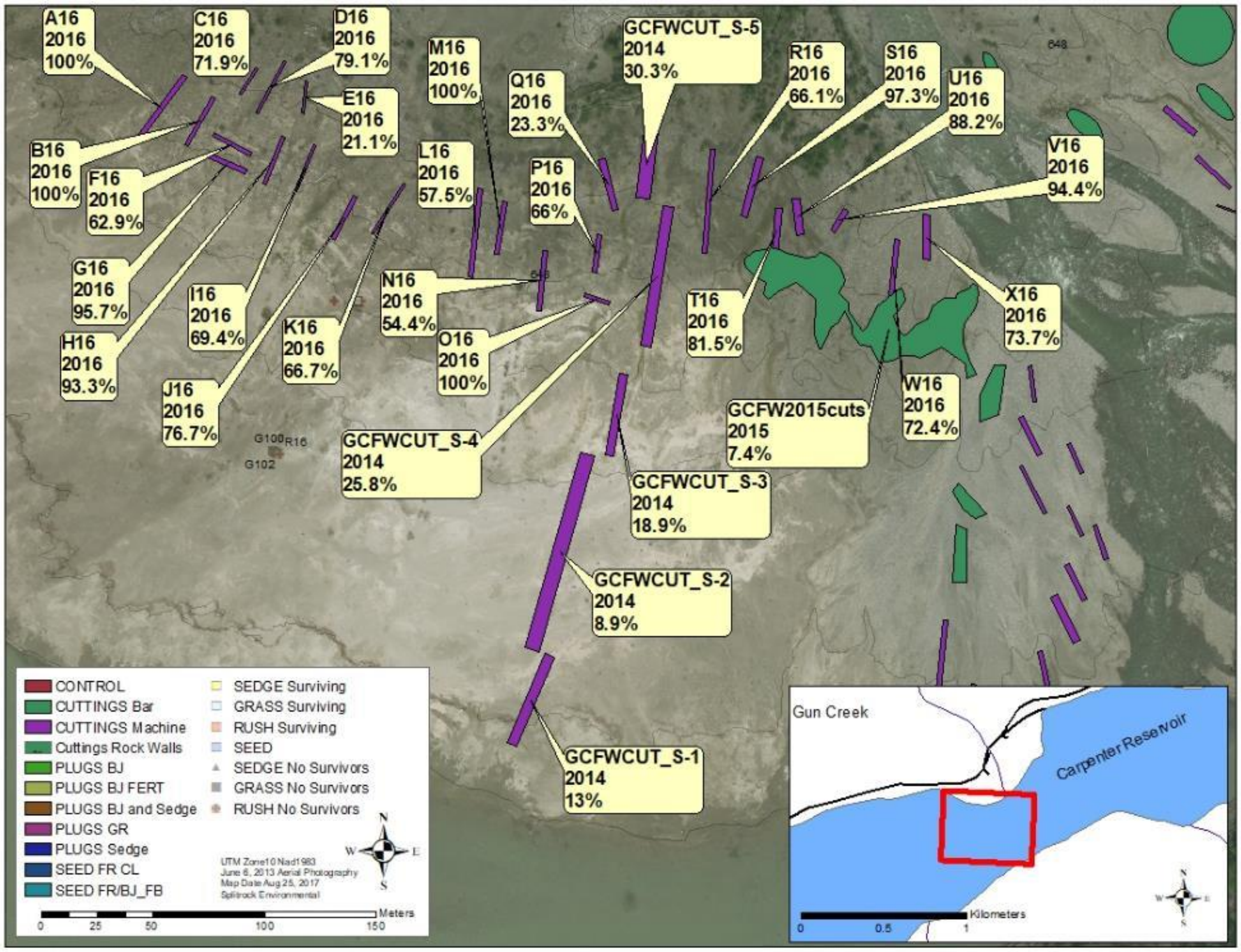
Map 21. Location of live-stake cuttings planted in GCFE terrain in 2015, with survival (%) observed during monitoring performed in 2016.

On the Gun Creek Fan West terrain, close to Gun Creek, linear trenches were planted with live-stake cuttings similarly to the east side of the creek. The seven polygons at the lowest elevation on the West side of the creek had no to little survival (A, B, C, D, E, G, H, Map 22). As in the East side, polygons at higher elevation had some successful establishment except for polygon N. Establishment of live-stake cuttings was low (only two polygons had live stems) in the four hand-planted polygons on the West side of Gun Creek (Map 22, Map 23).

Cuttings survival among the 2014 treatments was relatively high in the three polygons situated above 646m elevation (GCFW cuts S-3, S4 and S5) with percent survival increasing with elevation. Below the 646m willow cuttings from 2014 have survived in what appear to be localized sites that may indicate access to subsurface moisture. In GCFWCUT-S1 the surviving stakes are all located at the lowest point of elevation in the polygon, closest to the river. In GCFWCUT S-2 the surviving stems are located in a cluster located mid-elevation of the polygon. The groupings of the survivors may indicate site suitable site conditions are rooted in elevation and subsurface conditions. There may be merit in conducting future treatments that involve planting more cuttings working horizontally out from these sites that have shown some survival success. It is of note that although the cuttings are surviving here they are not necessarily thriving i.e., growth rates are relatively low for willow plants compared with willows growing in optimum conditions.



Map 22. Location of live-stake cuttings planted in GCFW terrain in 2015, with survival (%) observed during monitoring performed in 2016.



Map 23 Location of live-stake cuttings planted in GCFW terrain in 2014 and 2016, with survival (%) observed during monitoring performed in 2016.

5.0 Discussion

The management question addressed by the annual report for BRGMON-2 in 2016 is:

Does the implementation of a short term (5 yr.) intensive reservoir re-vegetation program result in benefits that were equal to or greater than that which were expected from implementation of the O3-2 operating alternative? (BC Hydro, 2012)[3]

The hypothesis tested by Component 2 of BRGMON-2 is:

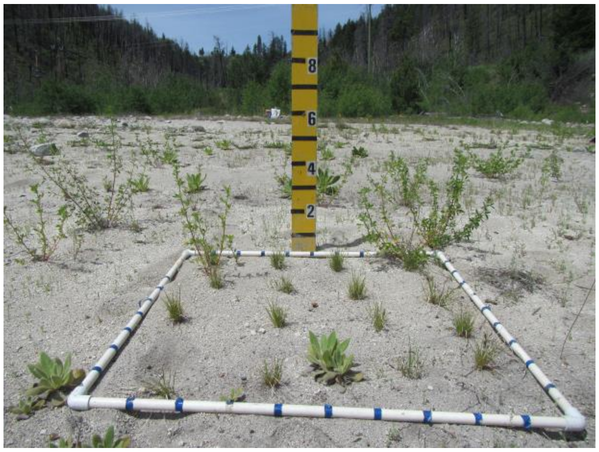
> H3: Implementation of extensive riparian planting for 5 years will provide the bases for continued natural re-colonization of the drawdown zone between the Gun Creek Fan and the Tyaughton Lake Road Junction.

The primary focus of the efforts performed under WORKS-1 in 2014, 2015 and now 2016, as based on the approach written in 2012 in the TOR, were to carry out restoration work and experiment with revegetation trials to assist and speed up the natural colonization of the drawdown zone of Carpenter Reservoir. We anticipate that it will take time for plants to establish, successfully reproduce, grow, and ultimately provide ecosystem functions such as cover, soil stabilization, and forage. It is still early in the program and we cannot answer the management question or the hypothesis (H3) at this time.

Monitoring of planted plugs in 2016

Results of monitoring the plantings of C. lenticularis plugs on mid and upper elevation sites at Steep Beach, Shallow Beach, Gun Creek Fan East and Gun Creek Fan West from 2014 indicated that survival was low and decreased over time at most locations. It would appear that over time the plugs once established are struggling to persist and most die in subsequent years. One notable exception was at the Shallow Beach (SHB) terrain where there was some indication of increased growth and cover by planted plants in 2016. The planted sedges at the SHB terrain provided the dominant portion of vegetation cover in sampled plots. Plants were surviving well but growing very slowly (Figure 21). The Shallow Beach site had coarse sandy substrate with a covering of the mount meager ash

[3] The BRGMON-2 TOR was revised in January 2017 but the current report is presented under the 2012 TOR that was applicable at the time of the monitoring in 2016.



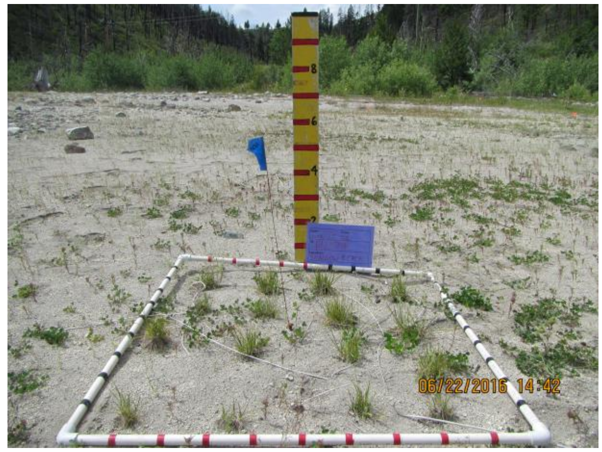


Figure 21 Shallow Beach plot P74, C. lenticularis plugs planted in 2014, photo June 2015 left, June 2016 right.

Survival of sedges in the 2014 strip plots was also down slightly between 2015 and 2016. Overall most of the plants planted in 2014 were persisting and not excelling in growth at any of the terrain types monitored in 2016 (STB, SHB, GCFE, GCFW and SAF). One exception was again at the Shallow Beach site where several plants were doing notably better and were in excellent conditions at the lower elevations (644-645 m ASL) of the strip plots, although poorly at higher elevations pointing to drought stress being a controlling factor for plant survival and vigor. Shallow Beach substrate is characterized by deposits of sands and Mount Meager pumice rock ash. Notable deposits of the ash are found on the Gun Creek fan West.

In 2015 the water levels in Carpenter Reservoir increased early, putting constraints on the length of growing season for re-vegetation trials using C. lenticularis at lower elevations (640m-644m). In 2015 treatments, low elevations were underwater within a week or two of planting. A very short settling period prior to flooding jeopardizes plant establishment, as planted plugs need time to root into the surrounding substrate to anchor themselves in place (Moodie 2016, personal communication). When inundated, planted plants are faced with hydraulic stresses and forces including wave action, floatation, erosion, scour, and deposition that can dislodge, uproot, or burry young plugs. This effect will be more evident in sites with sloped, loose unconsolidated substrates such as is found at the mid and upper elevations (644m) Shallow and (>640m) Steep Beach terrains. The early inundation in 2015 affected trials in polygon SHB15-CLEN (Map 12) and CLEN15 01-09 on the LMF terrain (Map 16, Figure 22). Many plants were observed to survive the short establishment period at low elevations, including polygon CLEN plots on the Low Mud Flat (Map 16). Also, observations in the Shallow Beach terrain indicated a high density of surviving plants, mostly located at the eastern end of the polygon SHB15-CLEN (Map 12), This was the lowest elevation where plants were flooded very soon after planting within a week (Figure 23).

A discrepancy is evident between the assessment of random plots on the CLEN15 polygons in LMF terrain (Figure 17) and complete survival tallies. Random plots indicated high plug survival with no obvious dead plants while polygon tallies indicated a range in survival with losses as high as 75%. It is likely that the low numbers and survival of planted plugs observed in random plots were due to plugs being lost to floatation and being washed away, especially in the case of polygon CLEN 05 (at 641 m ASL, Map 16).

One year after planting, total vegetation cover in the CLEN15 polygons located in LMF terrain was relatively low, with averages less than 10%. Seven out of eight polygons, and both treatment and control sections, were recorded with cover below or equal to 5%. Vegetation cover values < 10% are considered sparse structural development, which is the lowest possible structural development stage (BC Ministry of Forests and Range, 2010). This means vegetation covers and habitat provision of planted plugs in 2016, after one year of planting, was minimal. Plant development is ubiquitously slow throughout the treatment trials.

Figure 22. Photo of polygon CLEN 01 with the control section under water and the treated section in the foreground (June 5, 2015).

Figure 23. Photo of the east end of polygon CLEN-15 in SHB terrain where plug survival was notably high at low elevation. The approximate location of the flag that is visible in the lower right of the image is marked on Map 12.

Species composition of the LMF CLEN15 polygons was affected by treatment, with C. lenticularis sedge all but absent from control plots. The planting treatment has at least temporarily introduced a perennial native species to an area of the drawdown zone that is at this time not naturally recruiting the species. Naturally colonizing species in the LMF are dominated by a suite of low-lying annual species that form a sparse natural vegetation cover in the drawdown zone, including small exotic annuals including sand spurry (*Spergularia rubra*), common knotweed (*Polygonum arvense*), lamb's quarters (*Chenopodium alba*), and to a lesser extent, native small flowered evening star (*Mentzelia albicaulis*), Scouler's popcorn flower (*Plagiobothrys scouleri*), and wormseed mustard (*Erysimum cheiranthoides*).

Monitoring of seeding trials in 2016

Survival of grass treatment trials from 2014 into 2016 was very low. Of the five species tested Bluejoint reedgrass (*Calamagrostis canadensis*), fowl bluegrass (*Poa palustris*), foxtail barley (*Hordeum jubatum*), slender wheatgrass (*Elymus trachycaulus*), blue wildrye (*Elymus glaucus*) and the one rush species Baltic rush (*Juncus balticus*)), most trials failed. As with C. lenticularis there was a decline in survival with time. However, there are sparse cases where individuals of each species have survived. It is obvious that Baltic rush did not do well and should likely not be pursued as a candidate species unless specific conditions are identified where the rush may work. Alternatively, it may serve better as a secondary introduction species after pioneer species have established. Each of slender wheatgrass and blue wildrye, foxtail barley and bluejoint reedgrass had small numbers of surviving plants from 2014 treatments. The most positive results of grass and sedge trials from 2014 were in the Steep Beach, Shallow Beach (SHB) and Gun Creek Fan West terrains. Based on observations of the polygon treated with fertilizer in the SHB, it is apparent that nutrient input caused an almost explosive response in growth among the naturally colonizing plant species. It is likely that in coarse sandy soils, such as those found in the beaches, nutrients are limiting. It may be beneficial to conduct trials that over-seed selected plots or polygons with nitrogen fixing native plants, companion planting or over planting, and seeding desirable nitrogen-fixing species may act as a green mulch, add biomass and cover, and benefit struggling planted vegetation. *Lotus denticulatus* is a good candidate species for this type of trial, as it has been observed growing in dense patches at the eastern end of Carpenter Reservoir on a steep beach site (Scholz and Gibeau, 2013). *Lotus denticulatus* is a small native annual in the fabaceae family with a relatively large seed that could possibly be encouraged to grow and persist on treatment sites, particularly along perennial sedges.

Survival of grass trials planted in 2014 from 2015 to 2016 was greatly diminished at all sites, with no real stand out successes. All of the species that were planted in trials had some plants succeed but survival has declined between 2015 and 2016. It is likely, as with other terrestrial restoration projects in the area, that some degree of maintenance will be needed through the first, and ideally second, year of growth (particularly with respect to supplemental watering). The presence of coarse, mineral soil substrates with limited cover and shade, as well as hot summer temperatures, mean that moisture stress is likely a factor for both live-stake cuttings, plantings and seeding treatments prior to inundation. Maintenance could sustain plantings until root growth is established well enough for plants to better sustain the harsh site conditions. Changing site conditions to diversify microsites conditions would also likely improve survival (Evans, 2009; Polster, 2009). Follow-up fertilization or over-seeding with native legume species would also benefit plant vigor and survival.

As for planted sedges, limitation for the seeding trials at low elevation was a very short growing season for annual plants like fall rye in 2015. Fall rye was sown to test the effectiveness of introducing a fast growing, relatively high biomass-producing grass onto the barren site (Alberta Agriculture and Forestry, 2016). Seeding trials took place on May 25th which left only 140 AGGD for seeding treatments at 640 m ASL and 390 AGDD for polygons situated at 644 m ASL. Fall rye takes about 1000 AGDD to reach heading stage, so possible habitat values were reduced as the early inundation limited the time available for them to grow. The very short growing season did ensure however that there was no possibility for the seeded plants to produce seed, thus eliminating any concern that the plants could reproduce and spread. There was also limited time prior to flooding for germination and growth of seeded perennial species like C. lenticularis, making it unlikely that any germinant would survive the extended period of inundation. As expected, no one year old seedlings were observed during monitoring in 2016.

The tractor trials on the Seed plots 01-06 of LMF terrain (Map 16) were also hit with early inundation in 2015. The polygons that had the highest recorded number of C. lenticularis sprouts was 'Seed plot 01' which was the trial polygon located at the lowest elevation. It is likely that the observed C. lenticularis sprouts had germinated in 2016, and not from the original seeding trial of 2015. No seedlings were observed in 2016 that could have survived from 2015. It is impossible to say with certainty if the C. lenticularis seedlings observed during monitoring in 2016 were from the seeded trials or naturally colonized. However, the fact is that C. lenticularis seedlings were found in the highest density in the 'Control' sections of Seed Plot 01. Two polygons where no C. lenticularis seed was sown (Seed Plot 01, seeded with fall rye, and the mechanical-treatment only polygon) also had higher numbers of C. lenticularis seedlings. In all probability, these C. lenticularis seedlings sprang from seeds that were natural in origin and perhaps a result of the location of the polygon to the middle bridge river. Polygons sown with C. lenticularis and a mix of C. lenticularis and fall rye mixes in Seed Plot 01 were observed to have had fewer C. lenticularis seedlings. It is unclear why Seed Plot 01 had higher densities of seedlings than the other seed plot trials that had very few observable seedlings. Further investigation will be required to determine how widespread is the natural recruitment and long-term establishment of C. lenticularis. Based on anecdotal observations in the field, it appears that more C. lenticularis seedlings are recruited close to the river channel. Further study may provide more clear linkages between site factors and recruitment and also whether recruitment translates to establishment.

Seeded fall rye plants in Seed Plots (01-06) of the LMF and GCFE terrains germinated and grew to early stages of growth prior to being flooded out. Plants reached an early vegetative growth stage approximately 0.25m tall. There was no conclusive indication that seeding trials on the mud flats were having any beneficial impact on colonization of natural C. lenticularis. One interesting result from this seeding trial was that the polygon with the greatest occurrence of colonization by C. lenticularis seedlings was located at the lowest elevation close to the river. No C. lenticularis seedlings older than the current year's growth were observed, suggesting that all colonizing sedges are subsequently killed off either prior to or during inundation. We suggest that C. lenticularis seed deposited annually at the low elevations (<642m) of the LMF is germinating in the following years but that recruitment is sparse and survival is only temporary. The amount of seed that is recruited at LMF locations may be dependant on reservoir filling patterns or perhaps Bridge River flows that enable seed transport and deposition via hydrochory. C. lenticularis seed has been observed to have a dispersal window between mid June and mid July on Carpenter Reservoir. It is hypothesized that the majority of the highly buoyant lenticularis seed dispersal would take place at the leading edge of the reservoir. If the reservoir levels are at between 639m and 642m elevation during seed dispersal window it is expected that there is a higher potential for seed recruitment (Table 4). Surface modifications should increase seed recruitment at these elevations. Seed deposited at low elevations may also require some disturbance to bind seed into the substrate for germination in the following year (s). Reservoir levels were within the LMF recruitment zone for an extended period in 2014 and not at all during 2015 and 2016. It is likely that seedlings observed germinating in 2016 were deposited in 2014. Future trials may experiment with substrate modifications at the low mud flat locations to raise the substrate in places to determine if complexed and higher microsites could recruit and sustain C. lenticularis plants beyond initial colonization. Subsequent monitoring should focus on determining if any C. lenticularis seedlings have survived into their second year, or if there is currently a process of annual colonization and subsequent die-off.

Table 4 Peak period for C. lenticularis seed dispersal and Carpenter Reservoir water levels over the past 17 years. Highlighted cells indicate period reservoir levels are within the upper elevation s of the Low Mud Flat where increased seedling recruitment is desirable.

Day-Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	17 yr AVG	10th perce	90th perce
12-Jun	633.789	633.331	630.489	635.886	637.296	641.288	641.837	635.031	635.23	632.977	637.024	635.737	634.384	636.552	639.98	643.45	635.61	636.46	633.1894	641.5076
13-Jun	633.985	633.597	631.262	636.361	637.63	641.457	642.27	635.206	635.355	633.488	637.49	636.115	634.747	636.716	640.13	643.65	635.65	636.77	633.5534	641.7822
14-Jun	634.156	633.869	632.079	636.74	637.871	641.609	642.71	635.36	635.502	633.973	638.029	636.657	635.142	636.883	640.25	643.80	635.62	637.07	633.9314	642.0494
15-Jun	634.435	634.153	633.003	636.997	637.937	641.73	643.185	635.492	635.645	634.42	638.467	636.991	635.441	637.04	640.39	643.94	635.62	637.35	634.3132	642.312
16-Jun	634.703	634.429	633.901	637.183	638.048	641.836	643.56	635.638	635.813	634.831	638.907	637.128	635.666	637.234	640.46	644.05	635.58	637.59	634.5934	642.5256
17-Jun	634.997	634.661	634.633	637.369	638.259	641.943	643.862	635.7	635.973	635.141	639.22	637.373	636.067	637.445	640.55	644.17	635.52	637.82	634.8626	642.7106
18-Jun	635.381	634.817	635.21	637.637	638.445	642.182	644.124	635.734	636.131	635.433	639.487	637.801	636.538	637.744	640.65	644.24	635.45	638.06	635.3126	642.9588
19-Jun	635.792	635.001	635.716	638.052	638.647	642.492	644.339	635.973	636.308	635.683	639.786	638.143	636.935	637.987	640.77	644.29	635.35	638.31	635.551	643.2108
20-Jun	636.155	635.249	636.223	638.349	638.865	642.787	644.516	636.232	636.451	635.87	640.084	638.546	637.263	638.246	640.86	644.29	635.25	638.54	635.6216	643.389
21-Jun	636.55	635.524	636.652	638.646	639.139	643.062	644.665	636.526	636.632	636.045	640.421	639.194	637.625	638.572	640.90	644.28	635.18	638.80	635.8366	643.5484
22-Jun	636.973	635.868	637.103	638.892	639.517	643.364	644.84	636.886	636.898	636.221	640.759	639.441	638.023	638.94	640.96	644.28	635.17	639.07	636.0798	643.7288
23-Jun	637.321	636.239	637.576	639.092	639.881	643.67	644.929	637.169	637.157	636.397	641.096	639.822	638.585	639.341	641.00	644.25	635.24	639.34	636.3338	643.9036
24-Jun	637.645	636.509	638.032	639.261	640.256	643.909	645.038	637.352	637.341	636.573	641.433	640.098	639.283	639.695	641.06	644.26	635.34	639.59	636.5474	644.0486
25-Jun	638.014	636.643	638.469	639.422	640.657	644.11	645.165	637.477	637.489	636.747	641.771	640.227	639.796	640.054	641.19	644.28	635.47	639.82	636.7054	644.1792
26-Jun	638.358	636.749	638.987	639.641	641.126	644.308	645.315	637.572	637.753	636.902	642.108	640.381	640.171	640.362	641.26	644.30	635.57	640.05	636.8408	644.302
27-Jun	638.7	636.903	639.655	639.922	641.538	644.452	645.563	637.666	638.043	637.054	642.446	640.662	640.515	640.611	641.41	644.34	635.65	640.30	636.9936	644.3836
28-Jun	639.069	637.17	640.29	640.246	641.821	644.6	645.805	637.801	638.333	637.205	642.783	640.956	640.765	640.821	641.59	644.39	635.75	640.55	637.191	644.4758
29-Jun	639.523	637.472	640.877	640.57	642.003	644.8	646.073	637.991	638.623	637.357	643.108	641.321	640.991	641.166	641.68	644.46	635.86	640.82	637.426	644.5984
30-Jun	639.968	637.692	641.367	640.924	642.178	644.98	646.306	638.266	638.914	637.508	643.392	641.769	641.271	641.478	641.74	644.58	636.06	641.08	637.6184	644.7412
01-Jul	640.37	637.895	641.711	641.309	642.332	645.158	646.487	638.517	639.204	637.659	643.597	642.11	641.577	641.821	641.76	644.66	636.23	641.32	637.8006	644.8562
02-Jul	640.785	638.061	641.958	641.54	642.486	645.279	646.688	638.716	639.492	637.81	643.751	642.232	641.86	642.183	641.81	644.70	636.42	641.52	637.9606	644.9298
03-Jul	641.104	638.214	642.209	641.696	642.659	645.396	646.888	638.907	639.895	637.961	643.906	642.286	642.111	642.622	641.90	644.74	636.66	641.72	638.1128	645.003
04-Jul	641.305	638.458	642.449	641.837	642.825	645.472	647.089	639.123	640.293	638.112	644.067	642.489	642.297	642.908	641.98	644.77	636.75	641.90	638.3196	645.0526
05-Jul	641.475	638.728	642.646	641.999	642.962	645.576	647.27	639.421	640.626	638.263	644.278	642.782	642.467	643.163	642.01	644.78	636.90	642.08	638.542	645.099
06-Jul	641.627	638.96	642.803	642.166	643.116	645.746	647.418	639.785	640.952	638.416	644.488	642.898	642.584	643.243	642.05	644.78	637.04	642.24	638.7424	645.1652
07-Jul	641.785	639.174	642.929	642.324	643.307	645.956	647.506	640.122	641.256	638.592	644.736	643.217	642.727	643.395	642.10	644.78	637.20	642.42	638.9412	645.248
08-Jul	641.988	639.392	643.083	642.475	643.425	646.059	647.548	640.378	641.462	638.773	645.082	643.501	642.9	643.443	642.14	644.75	637.27	642.57	639.1444	645.4728
09-Jul	642.202	639.586	643.249	642.597	643.522	646.199	647.619	640.608	641.655	638.949	645.483	643.776	643.116	643.516	642.20	644.73	637.31	642.73	639.3312	645.7694
10-Jul	642.459	639.769	643.451	642.706	643.6	646.302	647.731	640.865	641.842	639.066	645.925	643.897	643.4	643.602	642.26	644.73	637.41	642.88	639.4878	646.0758
11-Jul	642.744	639.991	643.704	642.851	643.683	646.375	647.804	641.23	641.998	639.208	646.337	643.973	643.683	643.804	642.14	644.71	637.51	643.04	639.6778	646.3522
12-Jul	642.981	640.21	644.014	643.013	643.753	646.499	647.83	641.669	642.074	639.379	646.784	644.186	643.94	643.838	642.28	644.82	637.58	643.23	639.8776	646.613
13-Jul	643.198	640.357	644.293	643.203	643.829	646.664	647.838	642.105	642.18	639.544	647.148	644.366	644.197	643.921	642.38	644.87	637.65	643.40	640.0318	646.8576
14-Jul	643.401	640.505	644.597	643.403	643.908	646.793	647.845	642.564	642.314	639.719	647.342	644.602	644.482	644.221	642.34	644.91	637.71	643.57	640.1906	647.0126
15-Jul	643.583	640.68	644.872	643.573	643.957	646.898	647.848	642.998	642.357	639.894	647.548	644.896	644.82	644.391	642.53	644.93	637.76	643.74	640.3656	647.158

Bluejoint reedgrass planted into larger polygons in 2015 at the GCFE and West terrains had reasonable, survival with an estimated range in survival between 50 and 100 %, survival. Bluejoint has established naturally on the Gun Creek Fan, and its moderate tolerance for both flooding and drought (Carson, 2017) should make it a good candidate for providing cover and habitat at the upper elevations (above 646 m ASL) of the drawdown and buffer zones. Any fear of Bluejoint monocultures developing and ‘taking over’ is arguably unfounded at this site as there is little in the way of native herb cover and limited opportunity for establishment of other woody species this far down in the drawdown zone. Savannah sparrows (*Passerculus sandwhichensis*) have been observed using patches of bluejoint to take cover in natural clumps. Sparse clumps of bluejoint have been observed establishing at sites near Gun Creek where dust generation has been recorded (Scholz, 2015), and promoting more establishment of Bluejoint at these sites may have a beneficial effect on reducing dust generation.

Monitoring of live-stake cuttings

The success of the planting of live-stake cuttings in 2014 varied in 2016, with the highest success being found at the Steep Beach (STB) and Gun Creek Fan West (GCFW) terrains. The STB west end had 22% survival through its second growing season, and survival at GCFW terrain varied between 9 % and 30 %. This level of survival can be considered successful given a complete lack of maintenance, including no watering during very dry growing conditions. The trials conducted in 2015 suffered a lot of loss. Machine-trench plantings were centered around the outflow of Gun Creek where sub-surface and surface waters from the creek were expected to assist with establishment. Plantings at higher elevation seemed to do best. Damage from ice and debris flow was significant at lower elevations and, in concert with longer inundation, proved less conducive for cuttings survival and establishment (Figure 24). It also appears that cottonwood survival was less successful than that of willows. We recommended that future cuttings trials focus more on the use of willows. Also, to speed up development of riparian forest structure within the buffer zone, trials should be initiated with rooted cottonwood seedlings, trembling aspen (*Populus tremuloides*) and even Ponderosa pine (*Pinus ponderosa*) which was observed to have high flood tolerance for short durations (Klinka et al. 2000), and may be appropriate to trial in the upper buffer zone of the Gun Creek Fan.

Planting of live-stake cuttings occurred again in April 2016 on the Gun Creek Fan West side. They were monitored in June 2016 and losses over the first two months ranged from 75% to less than 10% at machine-excavated sites (Map 23). These plantings had been watered in and cuttings were soaked pre-planting (Scholz, 2016). Mule deer were observed browsing on the Gun Creek Fan West and they were likely having some impact on planted cuttings. It is obvious that, even with maintenance, there are losses early on with live-stake cuttings.

Anecdotally, the rock wall features constructed by hand on the GCFE and at the STB terrains had no obvious effect on either plant recruitment and growth nor on sediment collection. It may take a number of flooding events for substantial effects to be realized, or maybe the rock walls need to be built bigger. Any future substrate modification trials should be accompanied by some form of topographical or substrate monitoring.

Figure 24 Photo of Gun Creek Fan West 2015 cuttings plantings, observe driftwood caught up against cuttings

Monitoring of Hypothesis H2

A second hypothesis included in the BRGMON-2 TOR concerns water level inundation duration:

> H2: Incursions of less than 56 days into the reservoir buffer do not significantly impact riparian community.

This hypothesis is intended to trigger studies if and when these conditions are met. These conditions could be considered to have been met in 2015 based on BC Hydro Power Records reports and depending on the interpretation of the buffer zone level.

The peak of inundation in 2015 occurred above the 90th percentile of reservoir levels since 2000, which was around the low elevation of the Buffer Zone (648 m ASL). The peak occurred from late August until early December 2015. Water levels were into the buffer zone for a total of 71 days (not contiguously) in 2015, and above 648 m ASL for 57 continuous days between September 21 and November 16. For two of the 57 continuous days, water levels were merely 3 cm and 9 cm above 648 m ASL, so the contiguous incursion into the buffer zone was between 3 cm and 84 cm of vertical inundation. The highest water level reached in 2015 was

648.84 m ASL on October 29. The area impacted within the buffer zone was likely not large but this situation prompts a closer look at the H_2 hypothesis. Reference to the H_2 hypothesis in the 2003 Consultative Committee Report (BC HYDRO and Compass, 2003) suggests 648.9m as the lower limit of the Buffer zone. This level is 0.9m higher than the 648m referenced as the lower level of the Buffer Zone in the provincial comptroller of water rights 2011 Order. The incursions in 2015 were between these two values.

We need to clarify what conditions, i.e. perhaps levels of at least 0.9 - 1.0m vertical encroachment into the buffer for 56 days, will initiate a study to address the H2 hypothesis. The study design should also be predetermined before the conditions are realized. The limited degree to which the reservoir water levels were above the low end of the buffer zone in 2015 would make it difficult to measure and attribute impacts of the incursions across such a narrow horizontal area. A key to a study design lies in clearly identifying monitoring targets. Based on the study of BRGMON-2 in 2013, we recommend monitoring on the biologically rich Upper Mud Flat (UMF) and Buffer Mud Flat (BMF) near the town of Gold bridge on the north side (river left of the Middle Bridge River) (Map 24). This would be a key place to target and monitor for obvious impacts of prolonged incursions within the buffer zone such as die-back or species composition shifts in either tree, shrub or herb layers. Loss of structure, composition or cover due to extended incursions into the buffer zone would indicate a negative impact on riparian vegetation habitat value. However, it is unlikely that 56 days of inundation would affect willow or cottonwood species (Whitlow and Harris, 1979. Amlin, 2000). Repeating the monitoring of the 2013 UMF and BMF permanent transects in the year following extended incursions in the buffer zone may be one way of looking for impacts of prolonged flooding. It is debatable if monitoring should be initiated in 2017.

Map 24. Location of the permanent transects from 2013 in the buffer mud flats (BMF) and Upper Mud Flats (UMF) terrain at the far west end of Carpenter Reservoir.

Importance of fertilization

It was obvious from observations of the tea bag fertilized plot on the SHB terrain that there is a short-term effect on natural vegetation when the site is fertilized (Figure 25. Fertilizer treatments post-revegetation treatment may be helping to improve planted plant vigor, growth and habitat value. Tea bags of organic based (non-fish) fertilizer are preferable to loose or liquid forms as tea bags are more targeted and buried deep enough to reduce the risk of loss from leaching into the water table. It is hypothesized that the complete destruction of the polygon planted with bluejoint reedgrass in SHB terrain was due to the plants being fertilized with fish fertilizer prior to planting. A grizzly bear is suspected of being responsible for digging up the entire area and uprooting all but a few of the planted plants (Figure 26). It is possible other wildlife were responsible for the destruction of planted vegetation, including mule deer and digging actions under shallow water levels by Canada geese (*Branta canadensis*) or beaver (*Castor canadensis*).

Regardless of the cause, it is perplexing that the same damage was not observed at the west end or CLEN polygon at lower elevations in SHB terrain, where the planted plants underwent the same treatments. The polygon at the east end in SHB terrain also had fertilizer bags planted along with planted sedges but no obvious disturbance. However, the survival rates at the east and west polygons were more or less equal, with very few plants found surviving at either site with and without obvious wildlife disturbance (Map 12). Differences in the microsites were noted between the two sections, with substrate at the east end being a soft, loose, sandy soil and at the west end being more coarse gravels and cobbles. Another notable difference between SHB polygons was that the east end trial was carried out using bluejoint reedgrass but C. lenticularis was used in the west end. The CLEN polygon was lower in elevation and had a mix of both sands and gravels.

It is recommended that fertilizer and companion planting trials be initiated in sites were success has been observed but vigor seems to decline as time progresses. A possible treatment method would be to revisit and fertilize plots established in 2014 (1X1m and/or strip plots) where survival has been recorded, or to establish plots within polygons where plants have survived well (e.g. SHB CLEN or CLEN-15 LMF polygons). Ecologically speaking, it would be better to do companion planting as opposed to fertilizer, but both should be tested and compared for efficacy.

Figure 25. Image showing a rare example of a surviving C. lenticularis plug in the fertilized polygon at the Shallow beach (SHB) terrain (SHBW CLEN FERT).

Figure 26. Image of the west end of the polygon SHBE BJ where the entire polygon was systematically dug, presumably by a grizzly bear. Only a few live plants were observed on March 29, 2016.

Overall conclusion

There is no question from the trial results as monitored in 2016 that the drawdown zone around Carpenter Reservoir is a very hostile site for successful natural or treated vegetation establishment. Inundation and drought are primary factors in limiting natural vegetation establishment. Other factors including substrate texture, nutrient levels, as well as erosion by wind and water. Coarse skeletal soils that dominant the Gun Creek Fan East and sections of the Shallow and Steep Beach are difficult sites to vegetation. The loose unconsolidated sloped nutrient poor sites on the steep beach are very challenging to vegetate using herbs. The finer substrates of the Low Mud Flat and Gun Creek Fan East side are supporting herbaceous species. Planting and revegetation trials are bypassing some filters with seed sources and early plant establishment to give species a head start on adapting to the challenging conditions posed by the reservoir. C. lenticularis and C. canadensis remain the two herbaceous species showing the most potential for long-term establishment in the drawdown zone of Carpenter Reservoir.

6.0 Recommendations

WORKS-1

A key aspect of the BRGMON-2 program was to help direct the efforts of WORKS-1. One of the challenges with the scheduling of the projects is that monitoring under BRGMON-2 is conducted after the optimum work window for WORKS-1. The WORKS-1 efforts for 2016 were conducted prior to the monitoring work that is covered in this report. This issue has been addressed through a 2017 revision of the project TOR. WORKS-1 efforts were guided by early observations in the spring of 2016 but did not have the full suite of monitoring results yet. Seeding trials were expanded in the LMF terrain as were planting of C. lenticularis plugs and C. canadensis plugs. Live-stake cuttings trials were shifted to higher elevations of the drawdown and buffer zones, and were confined for 2016 to the Gun Creek Fan West and one small pocket on the west end of the SHB terrains. Small pockets of rooted cottonwoods and trembling aspen plants were targeted for planted into the buffer zone on the GCFE and GCFW terrains. Other recommendations for 2016 and 2017 are summarized:

- Continue to ensure planting and seedling trials are conducted as early in the growing season as possible.

- Integrate a maintenance program into any annual re-vegetation efforts, particularly for any treatments carried out in the upper drawdown and buffer zones, and including watering plantings through first and possibly 2nd growing season.

- Expand planting of C. lenticularis plugs in polygon trials within the 640m-644m elevation bands of the LMF terrain.

- Experiment with modifications of the substrate around SEED plot 01 in an attempt to recruit and sustain C. lenticularis seedlings into second and third year of growth. Compare effects of tractor-driven plough furrows vs excavator mounding.

- Conduct trials using meadow trefoil (*Lotus denticulatus*) with seeds gathered locally, as a native nitrogen-fixing annual species. Monitor growth and development over plots and polygons with established seeds to determine if plants can grow to reproduce and if seeds remain on site to propagate the following year.

- Conduct more fertilizer trials hitting sites where plants have survived well but growth has been minimal, example LMF CLEN polygons. Compare results with L. denticulatus trials.

- Expand revegetation trials by planting rooted trees into the buffer zone, particularly black cottonwood (*Populus balsamifera ssp. trichocarpa*), trembling aspen (*Populus tremuloides*) and even Ponderosa pine (*Pinus ponderosa*) in the upper buffer zone (649-650 m ASL).

- Conduct trials in the lower buffer and upper drawdown zones by expanding C. canadensis planting trials around Gun Creek.

- Continue planting live-stake cuttings in the upper drawdown and buffer zones to advance the structural development of habitat. Carry out ongoing maintenance, including watering through the first growing season, and focus efforts on the use of willows.

- Carry out micro-topography modifications to improve planting conditions at various sites throughout the drawdown zone.

- Continue trial planting of fall rye, as well as native species like C. lenticularis and Canada wildrye, on the LMF to test if there are positive effects on dust control and microsite conditions as well as improving temporary habitat values.

BRGMON-2

- Develop a strategy and implement ground work for addressing the H2 hypothesis when criteria are met.

- Eliminate future monitoring of all 1X1m plots from 2014 that had zero survival in 2016.

- Monitor again the 2013 permanent transects within the target revegetation zone as a reference and control for natural colonization, and analyze data as part of the mid-term comprehensive report in 2018.

- Recommend successional treatments within trials with established revegetation from 2014 and 2015 to incorporate legume seeding and fertilizer.

- In addition to survival, cover and vigor, focus monitoring on basal width of grasses and sedges rather than height.

- Continue with monitoring survival for planted polygons using 1X1m plot sampling, and ensure to extrapolate density measures to determine rates of survival.

- Include species diversity into all monitoring plots and, at a minimum, differentiate between coverage by native and exotic species to qualify natural species colonization.

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Appendix

The following is a summary of Reservoir management scenarios from (Compass Resource Management and BC Hydro, 2003).[i]

O3-2 This alternative is a refinement of Alternative L2. Alternative L2 delivered good wildlife habitat benefits on Carpenter Reservoir, but caused relatively high entrainment risks at Downton Reservoir. The Consultative Committee requested an alternative that would provide most of the wildlife habitat benefits in Carpenter Reservoir, but reduce the entrainment risks in Downton Reservoir. Alternative O3-2 maintains a maximum elevation of 647 m on Carpenter Reservoir, with excursions up to 651 m allowable for up to 8 weeks duration (versus no excursions as in Alternative L2). As with Alternative L2, there is no minimum on Downton Reservoir, however, the more flexible profile for Carpenter Reservoir coupled with different flow constraints on Middle Bridge River result in fewer deep drawdowns than under Alternative L2.

L2 In this alternative, Carpenter Reservoir is still constrained to remain below 647 m, but does not maximize littoral productivity over the bench at 637 m. This alternative provides wildlife habitat improvements on Carpenter Reservoir, but does not provide significant littoral benefits. No minimum reservoir elevation is set for Downton Reservoir.

N2-2P Alternative N2-2P is identical to Alternative N2-2, except that fall rye is planted in Carpenter Reservoir from the Gun Creek to Tyax Junction. This increases the wildlife habitat index to roughly the same value as for Alternative O3-2. However, there are some trade-offs: Alternative O3-2 delivers more cottonwood forest; Alternative N2-2P delivers more sedge grass/fall rye.

N2-2 This alternative is a refinement of Alternative N2. Relative to Alternative N2, the main change is a relaxation of the constraints on elevation of Downton Reservoir. Alternative N2 had a 718 minimum elevation constraint on Downton Reservoir. In order to achieve this, Middle Bridge River flows often dropped below 250 cfs. Alternative N2-2 holds Middle Bridge River flows at a minimum of 650 cfs, and as a result elevations in Downton Reservoir drop to (and sometimes slightly below) 710 m. The modelled constraints on Carpenter Reservoir are the same as Alternative N2, namely targeting a maximum of 648 m with excursions to 651 m allowable for up to 8 weeks. As shown in the resulting hydrographs (see Appendix E), this target is frequently violated in order to maintain the higher priority constraints downstream. Performance measure results incorporate this frequency. The model results also indicate that Carpenter Reservoir elevations are not expected to drop below 615 m, mitigating the entrainment concern.

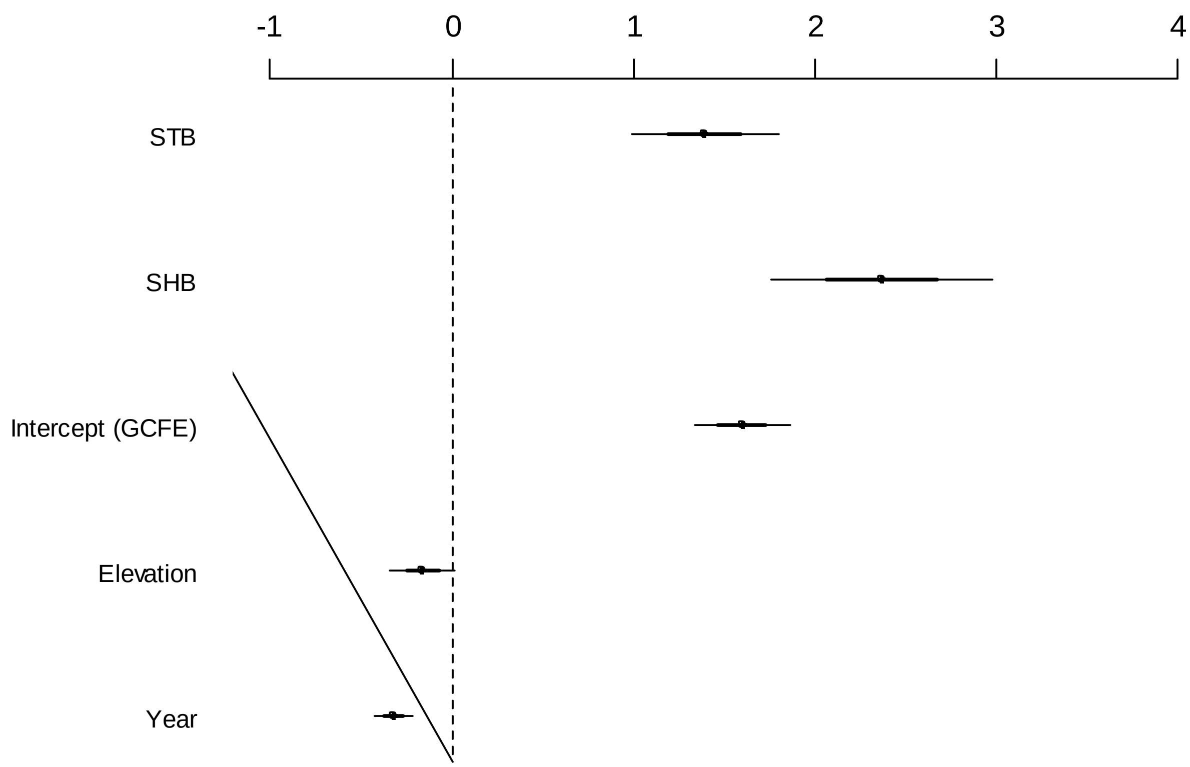

Figure A. Coefficient plots showing the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM for survival of CLEN, along with the 95 per cent confidence interval for fixed effects. Significance of the effects are: Year (t=-6.1, p=0.000), Elevation (-1.8, p=0.08), Intercept (GCFE, t=12.15, p=0.000), SHB (t=7.8, p=0.000), and STB (t=6.93, p=0.000).

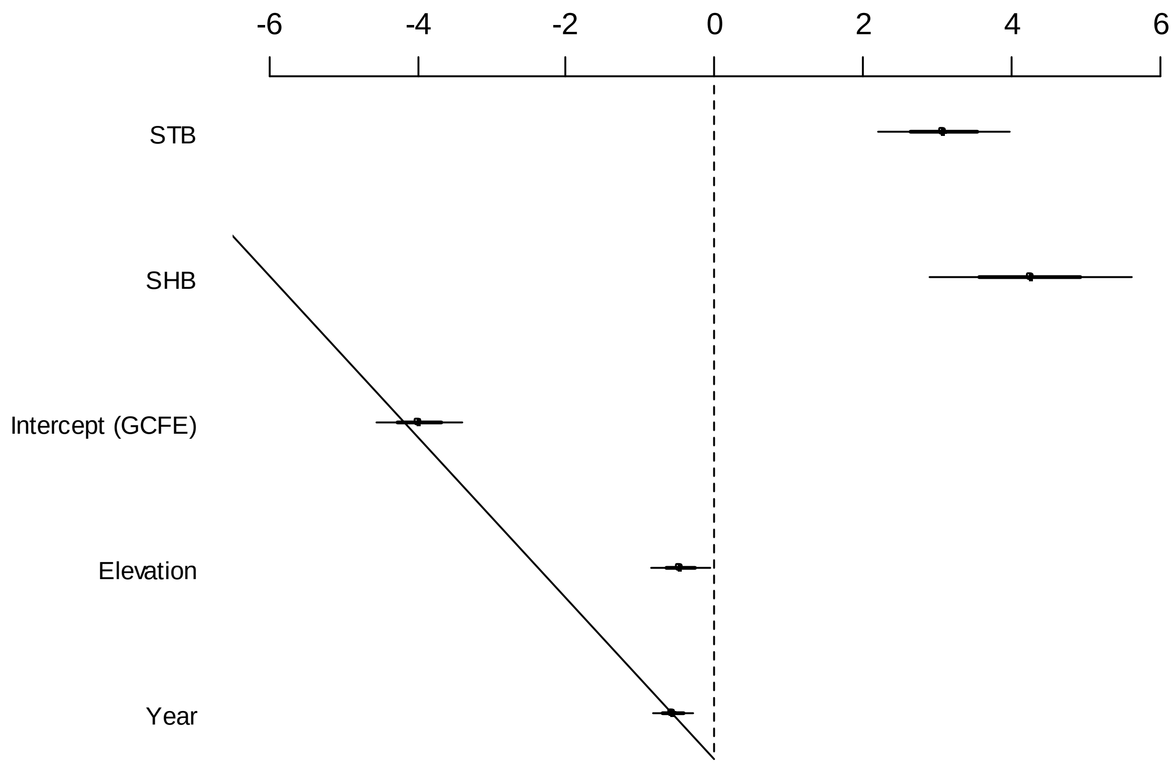

Figure B. Coefficient plots showing the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM for cover of planted vegetation in CLEN plots, along with the 95 per cent confidence interval for fixed effects. Significance of the effects are: Year (t=-4.2, p=0.0001), Elevation (-2.3, p=0.027), Intercept (GCFE, t=-13.6, p=0.000), SHB (t=6.3, p=0.0000), and STB (t=6.9, p=0.000).

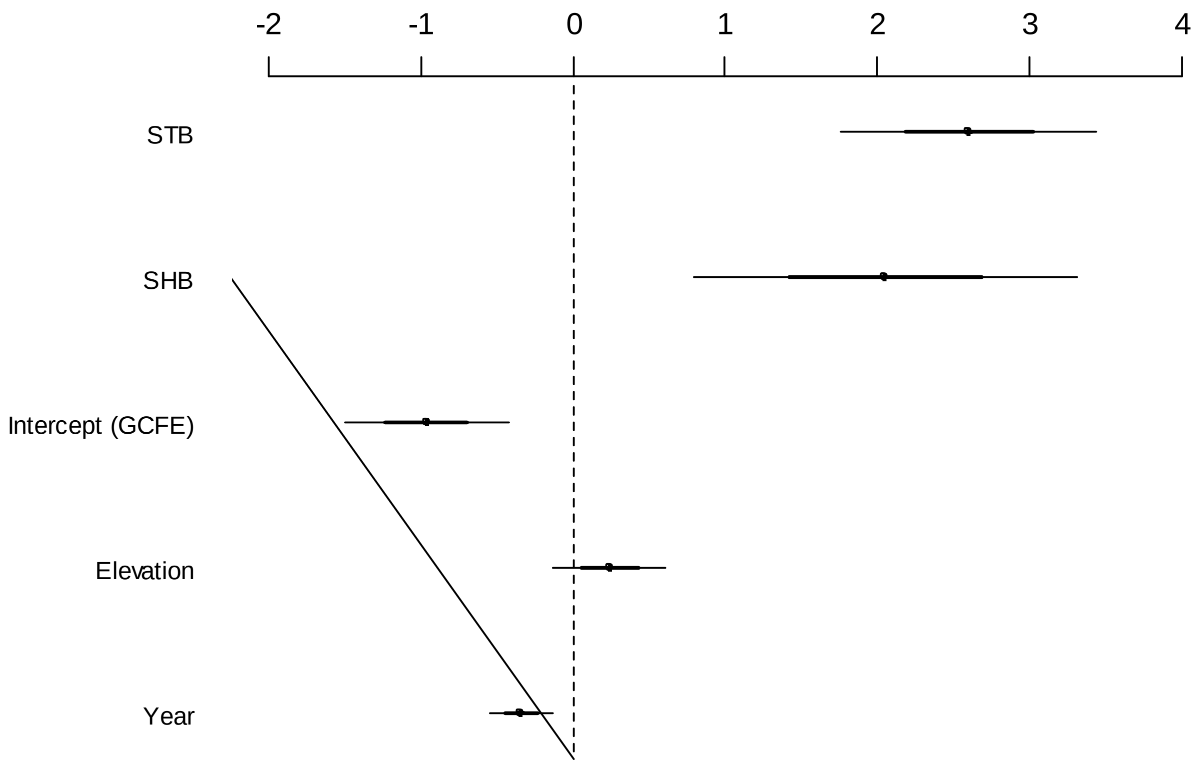

Figure C. Coefficient plots showing the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM for total cover of vegetation in CLEN plots, along with the 95 per cent confidence interval for fixed effects. Significance of the effects are: Year ($t=-3.3$, $p=0.0002$), Elevation (1.3, $p>0.1$), Intercept (GCFE, $t=-3.5$, $p=0.0008$), SHB ($t=3.2$, $p=0.002$), and STB ($t=6.1$, $p=0.000$).

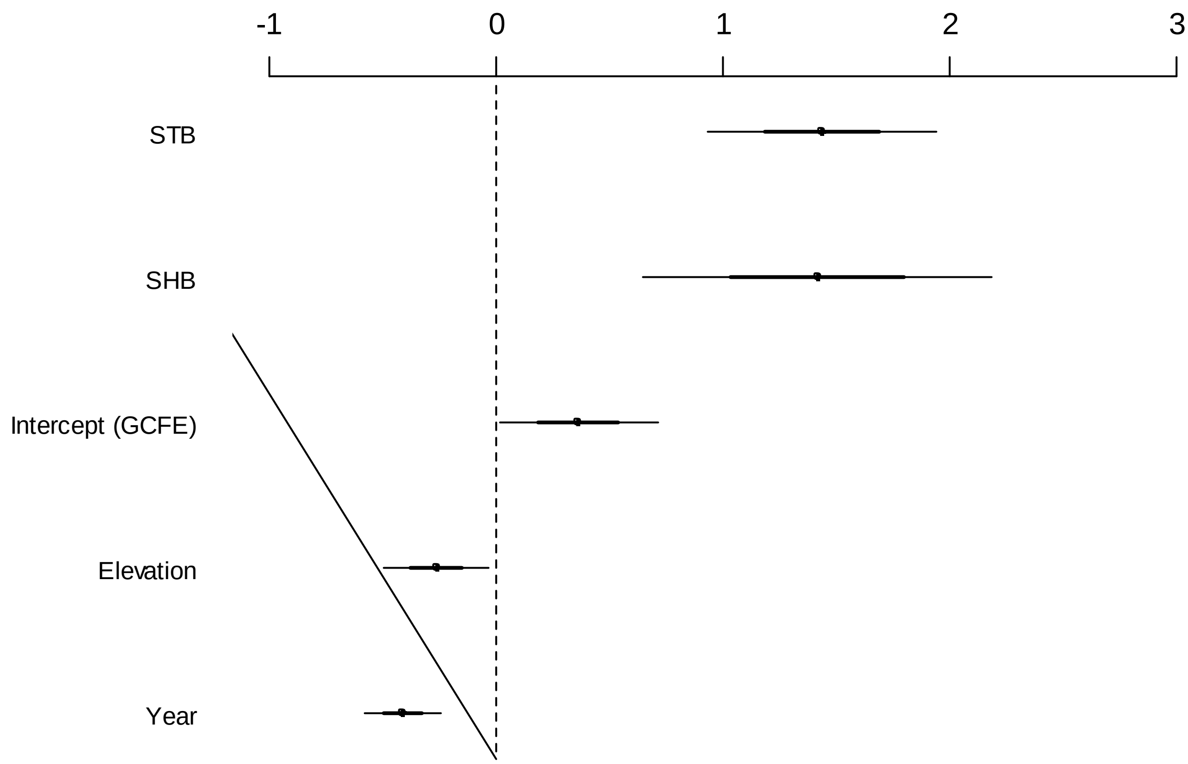

Figure D. Coefficient plots showing the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM for height of vegetation in CLEN plots, along with the 95 per cent confidence interval for fixed effects. Significance of the effects are: Year (t=-4.95, p=0.0000), Elevation (-2.3, p=0.026), Intercept (GCFE, t=2.1, p=0.04), SHB (t=3.7, p=0.0004), and STB (t=5.7, p=0.000).

Summary of the survival in 2016 of live-stake cuttings planted 2014- 2015.

Terrain type	Polygon	Treatment type	Year planted	No. planted	No. surviving in 2016	Survival in 2016 (%)
GCFE	GCFE_N_LOW	CUTTINGS Machine	2014	80	0	0.0
GCFE	GCFE_N_MID	CUTTINGS Machine	2014	120	0	0.0
GCFE	GCFE_N_UP	CUTTINGS Machine	2014	140	0	0.0
GCFE	GCFE_S_LOW	CUTTINGS Machine	2014	25	0	0.0
GCFE	GCFE_S_MID	CUTTINGS Machine	2014	310	4	1.3
GCFE	GCFE_S_UP	CUTTINGS Machine	2014	100	4	4.0
GCFE	A	CUTTINGS Machine	2015	20	0	0.0
GCFE	B	CUTTINGS Machine	2015	32	0	0.0
GCFE	C	CUTTINGS Machine	2015	80	0	0.0
GCFE	D	CUTTINGS Machine	2015	38	0	0.0
GCFE	E	CUTTINGS Machine	2015	37	0	0.0
GCFE	F	CUTTINGS Machine	2015	28	3	10.7
GCFE	G	CUTTINGS Machine	2015	35	2	5.7
GCFE	H	CUTTINGS Machine	2015	41	9	22.0
GCFE	HCUT15A	CUTTINGS Bar	2015	50	12	24.0
GCFE	HCUT15B	CUTTINGS Bar	2015	10	0	0.0
GCFE	HCUT15C	CUTTINGS Bar	2015	40	28	70.0
GCFE	HCUT15D	CUTTINGS Bar	2015	25	0	0.0
GCFE	I	CUTTINGS Machine	2015	39	18	46.2
GCFE	J	CUTTINGS Machine	2015	41	14	34.1

GCFE	K	CUTTINGS Machine	2015	44	4	9.1
GCFE	L	CUTTINGS Machine	2015	64	12	18.8
GCFE	Rock Wall 1	Cuttings Rock Walls	2015	10	0	0.0
GCFE	Rock Wall 2	Cuttings Rock Walls	2015	10	0	0.0
GCFE	Rock Wall 3	Cuttings Rock Walls	2015	10	0	0.0
GCFE	Rock Wall 4	Cuttings Rock Walls	2015	10	0	0.0
GCFE	Rock Wall 5	Cuttings Rock Walls	2015	15	0	0.0
GCFW	GCFWCUT_S-1	CUTTINGS Machine	2014	46	6	13.0
GCFW	GCFWCUT_S-2	CUTTINGS Machine	2014	90	8	8.9
GCFW	GCFWCUT_S-3	CUTTINGS Machine	2014	37	7	18.9
GCFW	GCFWCUT_S-4	CUTTINGS Machine	2014	66	17	25.8
GCFW	GCFWCUT_S-5	CUTTINGS Machine	2014	33	10	30.3
GCFW	A	CUTTINGS Machine	2015	31	0	0.0
GCFW	B	CUTTINGS Machine	2015	19	0	0.0
GCFW	C	CUTTINGS Machine	2015	24	0	0.0
GCFW	D	CUTTINGS Machine	2015	42	1	2.4
GCFW	E	CUTTINGS Machine	2015	40	0	0.0
GCFW	F	CUTTINGS Machine	2015	24	4	16.7
GCFW	G	CUTTINGS Machine	2015	79	0	0.0
GCFW	GCFW2015cuts	CUTTINGS Bar	2015	136	10	7.4
GCFW	GCFWHCUTS1	CUTTINGS Bar	2015	30	3	10.0
GCFW	GCFWHCUTS-2	CUTTINGS Bar	2015	16	0	0.0
GCFW	GCFWHCUTS-3	CUTTINGS Bar	2015	24	2	8.3
GCFW	H	CUTTINGS Machine	2015	21	0	1.0
GCFW	I	CUTTINGS Machine	2015	16	2	12.5
GCFW	J	CUTTINGS Machine	2015	34	0	0.0

GCFW	K	CUTTINGS Machine	2015	23	4	17.4
GCFW	L	CUTTINGS Machine	2015	31	3	9.7
GCFW	M	CUTTINGS Machine	2015	27	0	0.0
GCFW	N	CUTTINGS Machine	2015	16	0	0.0
GCFW	A16	CUTTINGS Machine	2016	41	41	100.0
GCFW	B16	CUTTINGS Machine	2016	41	41	100.0
GCFW	C16	CUTTINGS Machine	2016	32	23	71.9
GCFW	D16	CUTTINGS Machine	2016	43	34	79.1
GCFW	E16	CUTTINGS Machine	2016	38	8	21.1
GCFW	F16	CUTTINGS Machine	2016	35	22	62.9
GCFW	G16	CUTTINGS Machine	2016	47	45	95.7
GCFW	H16	CUTTINGS Machine	2016	75	70	93.3
GCFW	I16	CUTTINGS Machine	2016	36	25	69.4
GCFW	J16	CUTTINGS Machine	2016	43	33	76.7
GCFW	K16	CUTTINGS Machine	2016	51	34	66.7
GCFW	L16	CUTTINGS Machine	2016	73	42	57.5
GCFW	M16	CUTTINGS Machine	2016	46	46	100.0
GCFW	N16	CUTTINGS Machine	2016	57	31	54.4
GCFW	O16	CUTTINGS Machine	2016	29	0	0.0
GCFW	P16	CUTTINGS Machine	2016	27	0	0.0
GCFW	Q16	CUTTINGS Machine	2016	43	10	23.3
GCFW	R16	CUTTINGS Machine	2016	56	37	66.1
GCFW	S16	CUTTINGS Machine	2016	37	36	97.3
GCFW	T16	CUTTINGS Machine	2016	27	22	81.5

GCFW	U16	CUTTINGS Machine	2016	17	15	88.2
GCFW	V16	CUTTINGS Machine	2016	18	17	94.4
GCFW	W16	CUTTINGS Machine	2016	29	21	72.4
GCFW	X16	CUTTINGS Machine	2016	19	14	73.7
SAF	SAF_E_MID	CUTTINGS Bar	2014	57	2	3.5
SAF	SAF_E_UP	CUTTINGS Bar	2014	32	2	6.3
SAF	SAF_W_LOW	CUTTINGS Bar	2014	14	0	0.0
SAF	SAF_W_MID	CUTTINGS Bar	2014	27	0	0.0
SAF	SAF_W_UP	CUTTINGS Bar	2014	13	0	0.0
SAF	SAFE_LOW	CUTTINGS Bar	2014	32	0	0.0
SAF	SAF_Cuts_2015	CUTTINGS Bar	2015	533	21	3.9
SHB	SHBE_HCUTS_LOW	CUTTINGS Bar	2014	39	1	2.6
SHB	SHBE_HCUTS_UP	CUTTINGS Bar	2014	40	0	0.0
SHB	SHB15 cuts	CUTTINGS Bar	2015	116	27	23.3
SHB	SHBW_HCUTS	CUTTINGS Bar	2016	136	124	91.2
STB	STB_E_HCUTS_LOW	CUTTINGS Bar	2014	34	5	14.7
STB	STB_E_UP	CUTTINGS Bar	2014	20	0	0.0
STB	STB_W_HCUTS	CUTTINGS Bar	2014	99	22	22.2
STB	STB CUTS 2015	CUTTINGS Bar	2015	125	1	0.8
STB	STB2015 CUTS SMILE	CUTTINGS Bar	2015	10	0	0.0
STB	STBCUTS MIDDLE 2015	CUTTINGS Bar	2015	48	25	52.1
STB	STBCUTS SMILE	CUTTINGS Bar	2015	200	4	2.0
STB	STBCUTS SMILE POLY	CUTTINGS Bar	2015	48	0	0.0
STB	STBEast_Cuts 2015	CUTTINGS Bar	2015	155	30	19.4